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OF THE

New York State Museum

FREDERICK J. H. MERRILL, *Director*

VOL. 6 No. 30

November 1899

PETROLEUM AND NATURAL GAS

IN

NEW YORK

BY

EDWARD ORTON, LL.D.

ALBANY

UNIVERSITY OF THE STATE OF NEW YORK

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NOTE

The results here given are of investigations by Prof. Orton carried on during the season of 1897 at the instance of the late Prof. James Hall, state geologist and paleontologist, and were communicated with the annual report of that year; but it has since been judged wise, in view of the far-reaching importance of this paper and in order to secure its wider diffusion, to issue it separately as a museum bulletin. The paper is therefore appended to the museum report for 1899.

In references, volume and page numbers are separated by a colon; e. g. 16: 467 means vol. 16, p. 467.

JOHN M. CLARKE

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EDWARD ORTON, LL. D. 1829-99

The distinguished author of this bulletin, Edward Orton, LL.D., died at his home, Columbus, Ohio, Oct. 16, 1899 after a brief illness. He had completed the reading of the proofs of this paper but a few days before this sad event.

Dr Orton was an eminent son of the state of New York and there is not a little appropriateness in the fact that this, the last of his scientific papers, is devoted to the interests of the state which saw his birth and the beginning of his scientific activities. He was born in the village of Deposit, Broome county in 1829, his father, Rev. S. G. Orton, being the minister of the presbyterian church in that place. In 1848 he graduated from Hamilton college and thereafter entered the Lane and Andover theological schools. Between these latter courses he studied at the Lawrence scientific school at Cambridge and here caught the inspiration of his future career.

In 1858 he became teacher of natural sciences in the state normal school at Albany and afterward served till 1865 as principal of the academy at Chester, Orange county. Hereafter his active interest and influence in education was transferred to the state of Ohio where he became successively president of Antioch college, president of the Ohio agricultural and mechanical college and first president of the Ohio state university. From the last named position he retired in 1881, retaining the chair of geology in that institution which he held till his death. In 1882 he was appointed state geologist of Ohio, having already served as assistant to the previous state geologist, Dr Newberry. He had been president of the Geological society of America and at the time of his death was president of the American association for the advancement of science.

Dr Orton was a man of many accomplishments and a wide diversity of interests. Though his life was one of great achievement and ended only after its full fruition, his loss is a grievous one to all students of American geology. Along the lines to which this bulletin specially pertains he had become the highest authority and most competent adviser.

PETROLEUM AND NATURAL GAS IN NEW YORK

CHAPTER 1

ORIGIN AND ACCUMULATION OF OIL AND GAS

The state of New York is comparatively poor in the two great forms of stored power; namely, coal and petroleum. Its metes and bounds were fixed long before the real value of coal could be properly appreciated, and also long before its place in the geologic scale had been determined, while as for petroleum and its most important derivative, natural gas, both of them continued to be regarded as nuisances to be abated rather than as a possible source of wealth, till about the middle of the present century.

Within the established boundaries of this state a few square miles of the rocks of the Carboniferous age are included in Chautauqua and Cattaraugus counties. These Carboniferous rocks are found as outliers on the high hills at the head of the present drainage systems and are obviously "remnants that remain" from and represent a great sheet that originally included all the outliers that we know and extended beyond them in all directions. These outliers are all fragments of the great conglomerate, and none of them contain coal seams of economic value.

Section 1

Geologic structure, as connected with the accumulation of oil and gas

As for the accumulation of oil and gas we have learned that they follow the great structural features of the strata in which they are contained, which were established in them largely at the time of the Appalachian revolution. No more important generalization has been established in this great section of economic geology and none more abundantly supported than this; namely, that oil, gas and water, the usual contents of buried porous strata, have been separated from one another under the influence of gravity and have been accumulated at different levels, in the order of their specific gravities, by the same force.

All the facts bearing on these points seem intelligible and rational. They are in accord with the teachings of physics and thus are what we should naturally expect to find in this field.

The principal structural features to which allusion has been made, are commonly known as anticlines, synclines and monoclines. The first of these terms is applied to a roof-shaped arrangement of the strata of a district, in which they decline in opposite directions from a given line called the axis. Sometimes the descent on the opposite sides is equal in amount, but more frequently it is unequal. The axis can generally be followed for a few miles in an approximately straight line, but in many cases its elevation is gradually lost. From the point where it thus disappears, it is quite likely to rise again in the same general direction and at perhaps the same elevation that it originally had. Of course, in such cases, all the fragments are counted as a single axis. Wherever a well-defined axis is found, one or more similar lines of structure are very likely to occur, approximately parallel to the first.

A syncline is a form of arrangement of the strata exactly opposite to the anticline already described. The strata are bent into a trough, instead of into a ridge. All the statements as to the amount and direction of the descent of the different sides that have just been made as to anticlines are to be applied to synclines, with the proper, i. e. reversed, qualifications. In a word, a syncline is the normal complement of an anticline, and when two parallel anticlines occur, the space intervening between them is necessarily occupied by a syncline.

A monocline is in effect an incomplete anticline or syncline. A stratum descending from an approximately horizontal position at a certain level to a lower level regains the original horizontal position after making the descent. It is as if nature began to build an anticline or syncline and was not able to finish it. Monoclines are of much less frequent occurrence than anticlines and synclines.

All these forms of structure are necessarily effected in the differentiation of the contents of a porous stratum. The water, which has been named as one of the three principal elements

contained in such strata, is in most instances saline. With respect to water found at a depth of 500 feet or more, the presumption in many parts of the world is that it is saline. Compounds of soda and potash are widely diffused in the crust and many of them are very soluble and are gathered, accordingly, in underground water. Where the arrangement of the rocks is such that outflow occurs, the soluble compounds will, in the course of time, have all been carried out, and the outflowing water may at last have a high degree of purity. But, in multitudes of instances, the porous strata are so folded that the water of large portions has no access to the surface. When the drill reaches such areas, concentrated brines are often found. Saline water is always heavier than fresh water. It is not uncommon to find these deep waters increased in gravity by one tenth beyond the proportions of pure water. It goes without saying, therefore, that the synclines of the porous rocks, would be occupied by these heavy waters, and it is equally obvious that all the oil will rise to the sides and summits of the arches unless gas accompanies the oil, in which case, the highest level will necessarily be occupied by the latter.

The great development of anticlines and synclines is to be found in mountain regions, and here they are shown in their most striking forms. Parts of the great Appalachian system afford the most complete exhibition of these types of structure that is known in the world, though the Jura mountains of western Europe also furnish admirable examples of folded rock series. It is not in mountain regions, however, where he that runs can read the arches, the elements that constitute them, their dips and their directions, that accumulations of petroleum are to be looked for. When the rocks are folded into great arches that constitute the principal scenic features of the regions which they occupy, they have not escaped fracture at their summits. Faulting has also taken place in numerous instances along their axes, and by these two agencies, namely, fractures and faults, great accumulations of oil and gas have been made impossible. Such fractures give rise to a slow escape of oil, gas or mineral water, the latter often being characterized by temperatures above the nor-

mal. These prolonged escapes of gas and oil constitute most of the so-called "surface indications" of petroleum.

The system of arches and folds above named, that find their chief development in mountain regions, and to which, in fact, the mountains mainly owe their origin, are the results of the contraction of the crust of the earth, apparently due to its cooling. In the Appalachian region of Pennsylvania, Claypole has calculated that the shortening in of the original crust has amounted to 88 miles out of 153 miles, the latter having been reduced to 65 miles. Heim has calculated that an original extent of 203 miles in the Alps has been reduced by folding and crumpling to 130 miles. The arches seem to have resulted from lateral pressure exerted from the side of the ocean. Their axes are approximately parallel to the ocean boundary. Their slopes are gentle on the southeast side and much sharper on the northwest. The strongest folds, as a rule, lie farthest to the eastward. Certainly they diminish in both hight and dip as they are followed westward. In western Pennsylvania, for example, the folds are so reduced that they do not necessarily form the uplands of the region. They can be followed only by determining the elevation of some well-marked bed or stratum, as a seam of coal or sheet of limestone, or some persistent bed of red or blue rock, the peculiarities or the composition of which are well known. By such facts, the reality of the arch is demonstrated and their directions and angles of pitch can be determined.

All the valuable accumulations of petroleum and its derivative, natural gas, in Pennsylvania, are confined to these flattened and dying arches, the slopes of which seldom exceed two or three degrees, and which generally need to be read in minutes instead of degrees. No accumulations are known where the arches show angles of descent of five or 10 degrees or more. It would seem that the strata were cracked in the bending, thus allowing the escape of all mobile substances inclosed in the porous rocks of the series.

Following the effects of the Appalachian revolution still farther westward, we come to the still feebler arches and monoclines of Ohio. Numerous cases have been found during the last few years in which the elevations of even the summits of the

arches have not been found sufficient to effect a separation of the petroliferous substances and the salt water. In the "Big Indian" oil field of Monroe county, Ohio, many cases have occurred in which three or four barrels of salt water are raised by the pumps for every barrel of oil. The latter is, however, frequently produced in amounts of hundreds of barrels in a day.

The best defined monocline known is the Macksburg oil field of Noble and Washington counties, Ohio. In this case it has been demonstrated that the Berea grit has been checked in its uniform descent to the southeastward, at the rate of 20′ or 30′ of a degree and that it lies nearly horizontal for the space of one mile. This horizontal portion has proved available as a storehouse of oil and gas, and a petroliferous production of considerable importance is distinctly referred to this structure, with gas on its western boundary and salt water on the east. We owe the determination of this monocline and the general facts of its productive power, to F. E. Minshall, of Marietta.

Coming back to New York, we find that it was invaded by the Appalachian revolution with its mountain-making forces in very much the same way that western Pennsylvania and eastern Ohio were affected. Through the southern counties of the state, low arches are produced, which lack the force necessary to make them recognizable as features of the present surface relief, but which, as exploration has proved, were ample for the separation of the oil and salt water that were tributary to its porous strata. All the extensions of the great Bradford oil fields into Cattaraugus and Allegany counties are examples. Of these the "Rixburg gas streak" is one of the best.

But while the eastern side of the continent owes to the Appalachian revolution the great features of its relief, it has not been limited to the orogenic activities of this period. Contraction and necessary readjustments of the crust were certainly in operation long before the close of paleozoic time, and the earliest formed strata were left in an uneven condition. The steady growth of the continent from the Canadian protaxis southward is responsible for structural facts of great importance, specially for the prevailing southerly dip that affects the entire state and that

contributes so much to the completeness of the geologic column of New York.

In these previous movements of the crust, more or less relief was given to the land surface or sea floors of the times in which they occurred, and many low arches and synclines resulted in this way; but no prevailing direction is thus far found in any of these ancient structures, aside from this southerly dip already named.

It is not counted necessary in a paper designed specially for the general reader, to furnish proof of the statements already made as to the order of arrangement of the several substances contained in porous rocks. It is enough to say that the facts from every oil field fall into line in support of these statements. Moreover they harmonize so well with the teachings of physics that they soon come to be counted necessary truths and no grounds are apparent from which attacks can be directed against them. Even the disposition to make such attacks seems to have passed away.

The Trenton limestone field or northwestern Ohio, one of the latest oil and gas fields to be exploited, furnishes the most satisfactory and conclusive proofs on all these points. Five or six feet of relief have proved ample to keep gas wells dry for days and weeks, and wells drilled solely for gas and operated as such, have been slowly turned into highly productive oil wells, and, in multitudes of cases, have, at a later date, been overrun with salt water.

Section 2

Origin of petroleum, natural gas, maltha and asphalt

The readers of this paper will expect some attempt to answer the questions that human curiosity everywhere raises as to the origin of the bituminous series. The series has long been known to man. We find mention of it in the oldest records and traditions of the race, but its real value and importance have been mainly developed in the present century and very largely in our own day.

The bituminous series contains at least four well-marked elements; namely, natural gas, petroleum, maltha or mineral tar,

asphalt. The probable order of their derivation is not the order given above. From petroleum as an original center the other three substances are seen to be easily derivable by natural and familiar processes. From deep-stored oil when brought to day natural gas is always given off. By the removal of the gaseous hydrocarbons, the gravity of the petroleum is increased and the process of oxidation sets in, the effect of which is to darken the oil and still further reduce its gravity. We advance but a little way along this line before we begin to withdraw the name of petroleum from the dark and viscous liquid that we find resulting and give the substance the more appropriate designation of mineral tar. It is also called maltha, which is an ancient and somewhat technical designation.

Now, if the mineral tar is still further exposed and oxidized, it loses its liquidity altogether and hardens into a black solid, dull or shining, as the case may be, called asphalt.

Further, the petroleum from which the latter products are derived has itself a wide range in gravity. Some examples of it run as light as 55° B. while in other cases heavy oils of less than 20° B. occur. In the latter case it is always possible to explain the facts by the loss of the volatile elements as they approach the surface. All shallow oils, under which designation are included the occurrences of petroleum within one or two hundred feet of the surface, are heavy. Some of them are too viscous to flow freely and are well adapted in the natural state to lubricating purposes.

Not only does the fact that gas, maltha and asphalt are easily derived from petroleum point to the latter as the original substance, but the facts as to the chemical composition of oil and gas respectively lead to the same conclusion. Natural gas consists essentially of light carburetted hydrogen (CH), while petroleum has a much more complex composition. The simplicity of the former points to it as the derived substance. It is therefore necessary to account for the origin of petroleum only. All its derivatives will be explained under the same head.

The subject has proved a tempting one for consideration and as the economic importance of the series has increased it has commanded more and more attention, till there is at the present day a voluminous literature devoted to it. In regard to the

question, from what source and by what process did petroleum originate, we find many and discordant answers. A distinguished German geologist, Prof. C. F. Zincken, of Leipzig, says that for this subject we can well adopt the inscription placed over a meteorite that fell, centuries ago in Germany. *Multi multa; omnes aliquid; nemo satis.* These words can be thus translated: "Many men say many things; everyone says something; nobody gives a satisfactory account." When we come to analyze the various answers as to the origin of petroleum the case is not as discouraging as this statement would lead us to conclude. There is one point of vital importance in the discussion, and in regard to this it may now be said that there is substantially an agreement among all geologists who have earned the right to speak on the question; and, what is equally to be desired, there is a rapidly growing accord among chemists who are prepared to apply first-hand knowledge to the discussion of the subject. The vital point above referred to is the question whether petroleum is the product of chemical affinity, exerted on inorganic matter, or whether it is a result of the transformation of substances that have been built up under the agency of life. It is the latter line of answers that has come to be universally accepted by geologists and it now looks as if there would soon be equal unanimity among chemists in regard to the same point.

Section 3

Theories of origin

a *Theory of inorganic origin*

It has been claimed by a number of chemists, some of whom hold high rank in the scientific world, that the several members of the bituminous series can be referred to a purely mineral origin. There are several phases of this doctrine. One of them seems to imply that the elements, carbon and hydrogen, are combined in the interior of the earth through the agency of the high temperatures prevailing there. This phase of the doctrine matches to but few facts in nature and does not appear to be making progress.

The most widely accepted theories as to the inorganic origin of petroleum are those that refer it to certain definite chemical

reactions. Two among these theories have obtained a wide circulation by reason of the high rank of their authors, but they can not be said to have gained an equally wide acceptance.

In 1866 Berthelot, professor of chemistry in the college of France, and distinguished by remarkable and epoch-making discoveries in organic chemistry, particularly as to the composition of alcohols and sugars and by the discovery of acetylene, advanced the theory that the interior of the earth contains free alkali metals (sodium and potassium) and that these elements, when acted on by carbonic acid or carbonates at a high temperature would form carbids of these metals, which, by the action of water, would form hydrocarbons analagous to those found in petroleum. In short, he proposed the theory that both liquids and gaseous hydrocarbons of the bituminous series would result if meteoric water carrying carbonic acid or earthy carbonates in solution should reach by infiltration the metallic masses above named at a white heat and under high pressure. The chemical reactions invoked under the conditions named are undoubtedly sound, and the bituminous series would unquestionably result if these conditions should be met. The recent production of calcium carbid by the electric furnace on a commercial scale and its common use in the production of acetylene gas as an illuminant have made the process familiar and have given to it an air of reality that it never before possessed.

The theory of Mendeljeff, the eminent Russian chemist, is founded on altogether similar lines, but is relieved from some of the glaring improbabilities of Berthelot's hypothesis. It was first announced in 1877 and has been revamped and restated by the author during the present decade. Mendeljeff is the author of one of the most remarkable generalizations ever made in the science of chemistry. It is known as the *periodic law*, and has given to the science the ability of predicting future discoveries, similar to that so long possessed by astronomy, and which is recognized by all as the crowning proof that a science has reached its perfect, though not necessarily, its completed stage. There is no higher name in chemistry today than that of Mendeljeff.

His theory in regard to petroleum formation is briefly this. He supposes the interior of the earth to contain large masses of

metallic iron and counts the formation of meteorites confirmatory of this conclusion. He also considers the specific gravity of the earth, which is 5.5 against 2.5 for its surface rocks as rendering it certain that the interior contains substances heavier than ordinary rocks. In these interior masses of metallic iron he supposes more or less carbid of iron to exist as in meteorites. Carbids of iron would also be formed by the descent of carbonated water as in Berthelot's theory. Water infiltrating through fissures in the crust would be turned into steam at the depth supposed, and attacking the carbid of iron, would give rise to the petroleum compounds. The steam already invoked exerts pressure enough to force the petroleum vapors back toward the surface till they would become condensed by cooling and would be stored in all porous rocks capable of containing them. This is by far the most widely known and powerfully supported theory of the inorganic origin of bitumens. Mendeljeff expresses himself as satisfied with it and declares that petroleum is as truly a product of chemical affinity as a veinstone or an ore. This theory seems to promise a continual production and thus an unfailing supply of oil and gas and is sure to be welcomed in every field that is entering on its exploitation.

In like manner chemists who have given but little attention to the geologic facts connected with oil and gas further than that they occur beneath the surface, finding a theory at hand explaining the origin of these interesting substances on sound chemical possibilities, have naturally turned to this explanation with prejudice in its favor. Occasionally, also, a geologist has been misled by it, but, little by little, as the far-fetched and highly improbable assumptions of this theory have come to be considered and as a far simpler and more probable account of the origin of bitumens is at hand, Mendeljeff's speculations have lost standing with men of a practical turn, both chemists and geologists, till of late years no one has been found to champion it as if he believed it. To geologists, indeed, it sounds like an echo from the 18th century. It takes its place with the " cloud-capped towers and gorgeous palaces " of the speculations of Werner's time, 100 years ago.

The latest vigorous defense of the theory in question was made in 1889 by Mr William Anderson, at that time president of the

mechanical section of the British association for the advancement of science, but this defense revealed such profound and surprising ignorance and misconception of the geologic facts as to the occurrence of petroleum that it necessarily lost weight with all who are familiar with these facts, and must have weakened rather than strengthened the theory itself. [For an examination of this defense see *Geology of Ohio, Annual report*, 1890, p. 61.] A weighty consideration in this connection is found in the geologic distribution of petroleum and its derivatives.

We can roughly divide the rocks of the earth's crust into two great series, namely, those in which organic remains are more or less abundant, and those in which no traces of life are found. Their absence in the latter case may be accounted for either because life had not been introduced at the time of their formation, or by reason of metamorphic changes that have supervened since their origin, by which all such traces, if ever present, have been removed. In the last named division, neither petroleum nor any of its derivatives is ever found, and all its occurrences are confined to the fossiliferous division. While Archaean rocks do not cover as large an area as the vast series formed in the ages of life, they are by no means insignificant in extent. 2,000,000 square miles in one continuous body are referred to this division in the Canadian protaxis alone, and in the other continental masses a like distribution is recognized.

A single exception as to the absence of the entire petroliferous series from the Archaean rocks must, however, be made. In a few localities in the uppermost division of this series in Ontario, considerable deposits of an asphalt-like material, thoroughly compressed and hardened, are found. It can be made to burn only under the most favorable conditions. That the substance originated in petroleum is highly probable, but it is to be borne in mind that the rocks in which it is contained bear unmistakable evidences of having been originally stratified. If stratified they may have contained the remains of life. But aside from this and probably a few other exceptional cases, petroleum and all the substances derived from it are wholly wanting in the Archaean rocks. There is not an oil field in the world in the rocks of this age.

This fact alone constitutes a weighty argument against the hypotheses already presented. If the real centers at which petroleum originated are to be found in the primeval crust, according to Berthelot and Mendeljeff, the carbonated water essential to the process would certainly have a shorter course in reaching these masses of uncombined elements or metallic carbids by descending through the uncovered Archaean than by going down through thousands of feet of the stratified and fossiliferous rocks that overlie this formation.

Another fact that bears against the theory named above is the steady and notable increase in bituminous products that has seemed to go forward throughout geologic history. Their maximum production was apparently reached in Tertiary time. But the internal heat of the earth, which is an important factor in the theories named has been gradually reduced during these same ages. The results are thus directly contradictory to those required by Berthelot's and Mendeljeff's assumptions.

We come, therefore, to another line of explanations.

b *Origin from organic sources*

The reference of petroleum to an organic source stands in very different relation to familiar facts from the theories already reviewed. Petroleum is a combustible substance and every other substance that we know in nature that can be burned is of organic origin. Moreover we can produce artificially from vegetable and animal substances gaseous and liquid compounds that are closely allied to the bituminous series or even identical with them. The manufacture of illuminating gas furnishes a case in point. We obtain by this process not only the volatile combustible, but the liquid coal tar as well, that is closely analogous to some of the petroleum compounds. Illuminating gas is ordinarily manufactured from bituminous coal, but we can use all varieties of vegetable and animal substances for the same purpose. Even street sweepings and the ordinary refuse of a city have been by a patented process applied to the same manufacture. The occurrence of gas at the bottoms of ponds, produced from decaying leaves, or in boulder clay, from buried vegetation, are phenomena of common note.

In addition to these facts it has been definitely established within the last 30 years that the genuine and unmistakable members of the petroleum group, including illuminating oil, lubricating oil, benzin and paraffin, can be obtained from the distillation of fish oil. The demonstration was first made by two American chemists, Messrs Warren and Storer, in 1867-68. 20 years afterward, Dr Carl Engler, of Carlsruhe, Germany, duplicated and extended their experiments. Based on these striking results, several chemists have lately advanced the claim that petroleum is altogether restricted to this particular origin, namely, to the fatty oils of fishes.

That this claim is altogether untenable may be seen, among other considerations, in the fact that the Trenton limestone oil field of Ohio and Indiana, at present the most important in the United States, antedates by vast periods of time the introduction of fishes into the geologic scale of the country at large.

Further, during the last year (1897) Dr S. P. Sadtler of Philadelphia, read a paper before the American philosophical society in which he announced the very interesting and important result of having obtained hydrocarbon oils of the true petroleum type by the distillation of the glycerids of oils derived from vegetable seeds, thus duplicating Dr Engler's results and confirming the charge of overhaste on the part of those who ascribe the origin of petroleum generally to products of the vertebrate subkingdom.

To the general statement, therefore, that the bituminous series, petroleum, gas, asphalt, etc. are all derived from organic sources, it can be safely said that at the present time all geologists subscribe. Prof. C. F. Zincken of Leipzig has recently said "Not a doubt any longer prevails as to the derivation of petroleum from organic matter." It appears also that chemists are generally coming to the same conclusion despite the brilliant but fanciful and unverifiable theories of Berthelot and Mendeljeff. It is entirely unnecessary to descend to the region of igneous fluidity to find the genesis of these invaluable substances because there is always an organic source nearer at hand. The law of "parsimony of force" is applicable to the case.

But though geologists are agreed as to the organic source of the petroleum series, when we inquire as to the probable mode

of their origin we find at once well marked differences of opinion and belief. One school declares that petroleum is the result of the *primary decomposition* of organic matter contained in the rocks under certain favoring conditions, while another and larger section holds that it is always the result of the *secondary decomposition* of organic matter, or, in other words, that it is due to a process of *destructive distillation.*

1 *Origin by primary decomposition.* Of the first view the late Dr T. S. Hunt is the chief exponent and defender. According to this theory the decomposition of organic matter was mainly effected *in situ*; that is, in the strata in which the materials were stored, and the resulting product is therefore mainly indigenous to the strata in which it is found. This last feature is seized on in many popular statements and a theory of indigenous origin is made to include the various forms of theories of this class.

Dr Hunt held that there was an accumulation of organic matter in oil-bearing rocks that passed by a peculiar form of decomposition or decay directly into petroleum; in other words, these substances, instead of passing into the usual products of decay, namely, carbonic acid, ammonia, water, etc. were transformed directly into the bituminous series. This author also strenuously urged that as limestones are essentially of organic origin it is to this form of rocks that we must look for the chief source of the production of petroleum. He insisted on this view a score of years before a barrel of oil was ever drawn from the limestone beds of the country. In the light of the remarkable stocks of oil and gas that have been derived from the Trenton limestone within the last dozen years, Dr Hunt's claims show great prescience and sagacity. He appears to very much better advantage in connection with this revolutionary discovery than any other geologist of his generation.

But *does* organic matter pass by primary or direct decomposition into petroleum? Have we any examples of this process in operation in the world today? This is a fair and would seem to be a crucial question. If it is an actual process in the world it ought somewhere to be found in operation.

Dr Hunt seemed to see this question in its true significance and lays a great deal of emphasis on the testimony of Messrs

Wall and Kruger as to the asphalt lake of the island of Trinidad. [*Proceedings*, Geological society of London, 1860]

These gentlemen declare that the organic matter contained in the shaly rocks in which the lake is included has undergone a special mineralization, producing bitumen in place of ordinary anthraciferous substances. "This operation is not attributable to heat nor to the nature of distillation, but is due to chemical reactions at the ordinary temperature and under the normal conditions of the climate. The proofs that this is the true mode of the generation of the asphalt, repose not only on the partial manner in which it is distributed in the strata, but also on numerous specimens of the organic bodies in the process of transformation and with the organic substance more or less obliterated. After the removal by solution of the bituminous material under the microscope a remarkable alteration and corrosion of the vegetable cells becomes apparent which is not presented in any other form of the mineralization of wood." [*Quarterly journal* Geological society of London, 16: 467]. If these claims were substantiated the question would seem to be settled, but unfortunately for them several later observers only fail to confirm them, but report distinctly different conditions.

A few years since the late Dr O. Fraas of Stuttgart, Germany, announced that petroleum is in process of formation in certain coral rocks of the Red sea, as the result of the direct transformation of the organic matter of the reef. If this statement could be proved it would also meet the demands of Hunt's theory; but geologists recognize the fact that there are other possible sources of the petroleum that appears in the reef, and Fraas's claims can not be counted as established till all such possibilities are excluded. There are other similar cases, but none of them are decisive.

On the whole it must be acknowledged that the crucial experiment remains to be brought forward that will establish the claim that petroleum is now in process of formation by the direct or primary decomposition of organic matter. There are multitudes of geologic facts that seem to be in harmony with this view, and it has never been definitely set aside or abandoned, but to

meet the demands of science we ought to find somewhere positive proof of its reality as a living force or process in nature.

2 *Origin by secondary decomposition or distillation.* That organic matter stored in the rocks can be converted by heat into the petroliferous series is amply demonstrated by the practical operation of the process referred to as the manufacture of illuminating gas and paraffin from coal, bituminous shale and organic waste. In the primary decomposition or decay of organic bodies no extraordinary force is needed to produce the result. The instability of the chemical elements involved is adequate. Through the agency of life these elements were temporarily combined into the complex atoms which constitute organic bodies, but as soon as the principle of life is withdrawn the elements tend to resume the simpler combinations out of which organic bodies were constructed.

In what is called the secondary decomposition of organic bodies the agency of unusual heat is called in. Just what the lowest temperature is at which this process goes forward has not been determined but probably no one would claim that it comes into operation below 400° F. and the usual temperature of the artificial process that we employ is probably twice this or such as is represented by a low red heat. This secondary decomposition is also called *dry* or *destructive distillation.* From the organic substances to be acted on, the atmosphere is excluded, and, by the application of heat, as above indicated, the atoms of the body are rearranged in the shape of hydrocarbon compounds, gaseous and liquid, and there is also left over from this process a carbon residue or coke. These two facts, a temperature of not less than 400° F. and a carbon residue are indispensable accompaniments or conditions of what we call dry or destructive distillation.

That this process or rather some modification of it which retains all its conditions is effective in nature there seems no reason to doubt. When molten rock is forced upward through a series of strata, some of which, as for example, carbonaceous shales, are loaded with the remains of animal or vegetable organisms, the conditions of a gas retort are practically reproduced. The exclusion of the atmosphere, the high temperature, the organic matter, the pressure, are all here, and we can not wonder at the appearance of hydrocarbon compounds essentially like the

products of the gas retort. The production of gas and petroleum in connection with volcanic agencies is of frequent occurrence and does not excite our wonder. It is easily explained in accordance with the principles above noted. In such cases the strata that are traversed by molten rock show the effect of the unusual heat to which they have been subjected by unmistakable transformations.

There seems therefore no reason to doubt that destructive distillation gives origin to some occurrences of the substances whose origin we are considering. But there are several strenuously urged and widely accepted theories that put this agency in the front rank and in reality make it the great source of petroleum. Two of these theories may be named in this connection: those, namely, of the late Dr J. S. Newberry and of Prof. S. F. Peckham.

Newberry's theory was the first to be fully and elaborately stated and was propounded at the right time, viz, just when petroleum was coming to its first full recognition. It seemed to match well with many familiar facts of observation and was accordingly received with something like enthusiasm, as giving an intelligible and rational answer to questions that everyone was asking.

It was first published in a paper on the rock oils of Ohio in the *Ohio agricultural report for* 1859. He says: "The precise process by which petroleum is evolved from carbonaceous matter contained in the rocks which furnish it is not yet fully known, because we can not in ordinary circumstances inspect it. We may fairly infer, however, that it is a distillation, but generally performed at a low temperature." Again he says: "The origin of these two hydrocarbons (petroleum and gas) is the same, and they are evolved simultaneously by the spontaneous distillation of carbonaceous rocks." [*Geology of Ohio*, 1: 192]

In Dr Newberry's view the great black shale of Ohio (Hamilton, Portage, Chemung) is the main source of the petroleum of the oil fields of western Pennsylvania, New York and eastern Ohio, which these shales underlie.

Prof. S. F. Peckham has furnished another statement of the distillation theory but has recognized the necessity of higher than normal temperature and has added a source of heat to

account for at least the Pennsylvania petroleum. This source of heat he finds in the rise of temperature attending metamorphism and developed by the elevation of the Appalachian mountain system. He says: "Bitumens are not products of the high temperatures and violent action of volcanos, but of the slow and gentle changes at low temperatures, due to metamorphic action on strata buried at immense depths."

Both of these theories are open to the objection that they use the term distillation in a different sense from that which it regularly holds. It is a technical word and has a definite meaning, but this meaning is ignored by both of the authors named. Newberry speaks of "low temperatures", evidently implying conditions either normal, or not far from normal and as still in progress. Peckham declares that "it is not likely that the usual form of destructive distillation as illustrated in a gas retort has obtained anywhere in the operations of nature." [*Proceedings*, American philosophical society, 1898]

To speak of distillation as going forward without a coke residue and at low or ordinary temperatures is pure assumption. For such a process we find no warrant in science. It is a matter of inference pure and simple. We find certain rocks with oil and gas which closely resemble the products of the dry distillation of organic bodies and we infer that the latter are due to a process that we choose to call by the same name, and we talk vaguely of time being exchanged for temperature as if the maintenance of a temperature of 100° for thousands of years could be made to do the work of a temperature of 1000° for a shorter time. All this may be true but there is no scientific demonstration of it. This distillation theory stands on very much the same basis as Hunt's theory of the primary decomposition of organic matter into the petroliferous series. The supposed facts adduced in support of it do not appear to stand examination.

The great difference between these two classes of theories seems to be that they assign very different dates for the origin of the petroleum found in the rocks. Hunt's view would refer it to the date of the formation of the rocks, the organic matter of which would be at once transformed into the permanent shape which we find in petroleum.

The distillation theory allows that the organic matter of the rocks passed for the time being through the anthraciferous state, in which it could remain indefinitely. Peckham's original theory referred the oil of Pennsylvania to the close of the Appalachian revolution, but his later statements seem to imply that he no longer considers this date of special importance. Newberry held that the process of petroleum production was in constant operation, but he recognized that the world is old and that vast periods of time have been open to the action of this process.

What geologists would be glad to find in nature as matching to and harmonizing with the facts with which they are obliged to reckon would be a process in which the products of the organic world are transformed into mineral oil at ordinary temperatures and with complete consumption of the substances acted on, so that no carbon residue would be left behind. They would also expect the transformation to be accomplished while the organic matter still retained essentially its original character.

The point of greatest importance is the ultimate source of the bituminous series. In regard to this, as already implied, both geologists and chemists are coming into full accord. Both find in the organic matters which the rocks contain or have contained in their past history a source at once abundant, everywhere at hand and competent to meet every demand. The oily substances escaping from the waste in gas manufacture naturally float on the surface of the water into which such waste may be conducted, but the fine particles of clay in the water unite with the oil and settle with it to the bottom. This represents a very important fact in nature and meets the objections that Mendeljeff and others have urged to the effect that petroleum, unless confined in the rocks, would rise to the surface of the sea and be at once wasted by exposure to the atmosphere. On the contrary we see that clay, the second substance in abundance in the crust of the earth, absorbs and protects the petroleum.

To this statement we can add another, namely, petroleum seems to be, when thus protected from the air, one of the durable forms that organic matter can assume. There seems no reason to believe that it is less permanent than coal. Stored in the rocks in the morning of the world it can apparently remain in this condition through the vast and indefinite ages of geology.

One qualification, perhaps, needs to be added; namely, that petroleum as stored in the rocks may be transformed there into the inflammable gas that belongs in the same chemical series and which may be even more stable than the oil, by as much as it is simpler in composition. It may even be that the oil would be entirely converted into gas in the process of the ages.

It seems altogether probable that the oil and gas which we find in the rocks are of widely different ages, corresponding to the ages of the formations in which they are stored. Thus we may have Cambrian, Ordovician, Silurian, Devonian, Carboniferous, Triassic, Jurassic, Cretaceous and Tertiary petroleums.

The facts of geology seem to show that it is exceedingly improbable that gas or oil have been transferred in a large way from one formation to another in the geologic column. This statement requires qualification. That there has been some transfer of petroleum and gas in the rocks is beyond question. They are associated with water and gravitation will always raise them to the highest point in the stratum in which they happen to be. If the reservoir was fractured at the summit of an arch these mobile substances will follow the lines of escape to the surface, if the latter extend thus far, and must certainly diffuse themselves through any porous beds which the fracture crosses.

With such escapes of oil and gas we are familiar. We call them "surface indications" and they often lead us directly to the storehouse from which they have issued.

In like manner a porous rock is often found stored with petroliferous products evidently derived from a stratum or bed directly underlying it. The most common form of such occurrence is a sandstone overlying a carbonaceous shale. When such a series rises to the surface the porous rock is often charged with maltha, resulting from the oxidation of the original petroleum. If the sandstone is in demand for building purposes, the tar is often found exuding from it, even for years. Tar springs, so called, have a like origin, the escaping water of the porous rock carrying out some of the inspissated petroleum.

CHAPTER 2

GEOLOGIC SCALE OF NEW YORK, AND ITS RELATION TO OIL AND GAS

The geologic scale of New York is more symmetric and complete than that of any other state of the Union. A greater number of changes in the conditions of the sea in which the successive deposits that compose the great part of the state were laid down is registered than is to be found elsewhere and many of these deposits obtained here their full development as far as both lithologic elements and fossil contents are concerned. We go to New York for the typical representation of most of the elements of the geologic scale of North America. In other words, the New York column is the typical column. When it is added that the systematic study of the geology of this country was begun by the state geological survey of New York and that the geographic names drawn from localities in that state are fixed on all the leading formations, and farther when it is remembered that the state survey has expended a large amount of money, in the description and representation of the fossils of its several divisions, it is easy to see that the geology of New York must, on all accounts, be regarded as the standard of the eastern side of the continent.

In the northern prolongation of the state known as the Adirondack highlands a considerable area of Archaean rocks is exposed. This area is now being studied, subdivided and mapped, and much light is being thrown on it by the work now in progress.

But leaving these old bottom rocks, unmistakably a part of the protaxis of North America and representing the most ancient foundations of the continent, we come to the great column of stratified rocks which constitutes one of the finest geologic series of the world, in which the progress of life is recorded as distinctly and with as few interruptions as perhaps in any other single section; as far, at least, as the base of the Carboniferous system.

The New York column is essentially a paleozoic column. All the great divisions of the paleozoic system are displayed in it except the Carboniferous and Permian and the latter are not altogether without representation.

Its main elements are of Cambrian, Ordovician, Silurian and Devonian time, with some representation, as indicated above, of the Subcarboniferous series. The divisions are given below in descending order.

Paleozoic	Carboniferous	Coal measures	Millstone grit
		Subcarboniferous	Mauch Chunk
	Devonian	Upper Devonian	Catskill
			Chemung
			Portage
		Middle Devonian	Hamilton
			Marcellus
		Corniferous	Corniferous
			Schoharie
		Oriskany	Oriskany
	Silurian	Lower Helderberg	Lower Helderberg
		Onondaga	Waterlime
			Salina
		Niagara	Niagara
			Clinton
			Medina
	Ordovician	Trenton	Hudson river
			Utica
			Trenton
		Canadian	Chazy
			Calciferous
	Cambrian	Upper	Potsdam
		Middle	Acadian
		Lower	Georgian

Of these several elements eight or 10 or more are sandstones. The best characterized sandstones are named below in ascending order. Potsdam, Hudson, in part; Medina, Oriskany, Portage in part; Chemung in part; Catskill, Pocono, Millstone grit.

Sandstones are the chief representatives of porous rocks and as such are the main repositories of underground waters, fresh or saline, and of petroleum and gas. All the strata named above serve in one or more of these several offices at some point within the limits of the state.

There are still other strata in the column which may contain water, oil or gas. Dolomitic limestones that have had a particular history are sometimes as porous as the coarsest sandstone. True limestones also in some of their phases show considerable storage capacity for gas and occasionally for water.

Porous dolomites seem to have resulted from the replacement of their rock substance. The first stage is pure limestone. Then by some change in the character of the sea water, magnesia is supplied in such quantity that it replaces one half of the limestone atoms, transforming the rock into a true dolomite. But the atom of magnesian carbonate is demonstrably smaller than the atom of calcium carbonate which it has replaced and if the original rock volume is maintained, vacant spaces must be left in the mass. Not all dolomites are porous. It is conceivable that dolomites originating in a different manner from that mentioned above may be compact and close grained rocks.

Concerning the reservoir qualities of limestones, we have not as good means of judging as of the rocks already described in which the porosity is a natural consequence of their physical state. Where limestones act as reservoirs there must be vacant spaces between the layers or beds of the stratum. That they are not true reservoir rocks is evident from the fact that they do not as a rule contain fresh or salt water in large volume. It seems probable, however, that the structural features of the strata contribute to the storage of gas.

CHAPTER 3

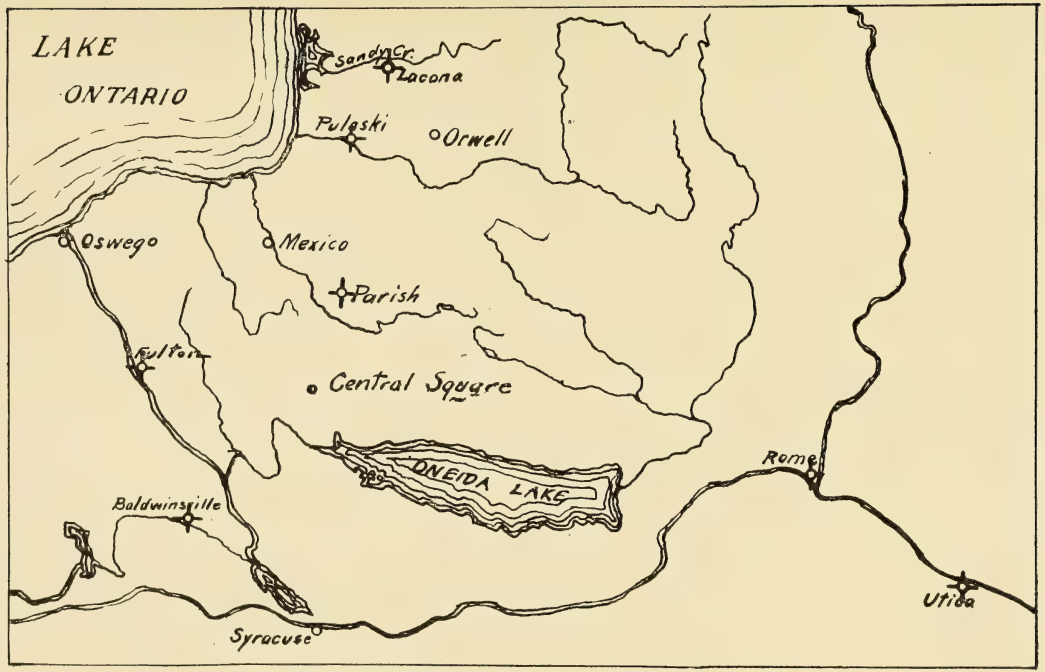
PRODUCTION OF GAS FROM THE LOWER FORMATIONS OF THE STATE

MEDINA, UTICA, TRENTON, POTSDAM

The discovery of petroleum on a large scale in this country was made at Titusville, Pa. in 1859. During the next few years explorations were eagerly carried forward and the geology of petroleum began forthwith to take shape. It was soon established that the great reservoir rocks of this region were sandstones or conglomerates that belonged to the Devonian age. The prompt but premature conclusion was at once reached by many of those interested in the subject that the natural home of petroleum was in the upper Devonian rocks of the geologic scale. But other horizons were developed as explorations proceeded and it was found necessary to include Subcarboniferous and finally Coal Measure sandstones among the sources of oil production and also to go lower in the scale and take in the middle Devonian as well.

With the geologic range as thus defined, namely from the middle Devonian through the Coal Measures, the drillers of western Pennsylvania and adjacent regions in New York, Ohio and West Virginia were content. Not an oil well was known outside of these limits and it came to be everywhere recognized as entirely practicable to determine on such a basis the regions in which the search for petroleum could be undertaken with fair prospects for success as well as the regions into which it would be folly to introduce the drill. This limit was practically in one direction only, namely, in descending the geologic column, for in eastern North America the Coal Measures are the latest formed and so the highest strata of the scale, with a few insignificant exceptions. But when Silurian or older rocks constitute the surface such territory was at once condemned, on the basis of the generalization above described.

The overthrow of this premature generalization came from northwestern Ohio in 1884-85 by the discovery of gas and oil in large amounts in the Trenton limestone. An immediate extension of the possible range of these substances was effected by this



Sketch map of central New York (in part).

discovery. It is true that an oil field of somewhat doubtful horizon and of rather insignificant production had already been developed in northwestern Ontario. The productive rock had been referred by Dr T. S. Hunt to the lower Devonian, and though this determination was questioned, the doubt was directed to a lower rather than a higher horizon, but no great weight was assigned to this oil field, so that the inclusion of the Trenton limestone among the productive oil rocks of the country came with a shock of surprise to both the scientific and the practical men interested in this question. The discovery carried the productive horizons of oil down several thousands of feet in vertical descent and enlarged the superficial area of possibly productive territory many fold. In fact, it transformed almost the entire area of the eastern United States into possible oil territory, so far as its range of rocks is concerned. The only regions excluded would be the Archaean district of New England, the Adirondack highlands, and the eastern or Blue Ridge portion of the Appalachian mountain system.

The Trenton limestone is by far the most widespread of any of the great sheets of stratified rock that make up this side of the continent and when it was recognized as a possible oil rock it carried over almost the entire country into this category.

Since 1884-85, the date of the discovery above named, one of the most important gas fields of the United States has been developed in the Trenton limestone of Ohio and Indiana, in regions where it lies 900 to 1200 feet below the surface and in the same region at a slightly greater depth one of the most important oil fields of the world has been brought to light, a field in which scores of six inch wells have each produced more than 100,000 barrels of oil, while single wells have passed the 200,000 barrel mark. The production of flowing wells has in many cases been at a rate of 10,000 barrels a day, and gas has flowed out from wells of the same size to the measured amount of ten, twenty and even thirty million feet a day. Entire farms have yielded oil to the amount of several thousand barrels to the acre. The initial rock pressure of the gas was between 400 and 500 pounds to the square inch in certain portions of the field. A total production of fifteen to twenty million

barrels of oil a year has been obtained in the Ohio and Indiana fields combined, in spite of determined attempts on the part of the Standard oil company to curtail production by depressing the price of crude oil below the point at which ordinary wells could be operated.

When the Ohio and Indiana fields were first studied, certain facts were brought to light in regard to the Trenton limestone that seemed greatly to restrict the promise which the announcement that this limestone is an oil rock would carry.

It was found that the petroliferous production was entirely limited to the uppermost beds of the formation, generally to the first 50 feet and never to more than 100 feet. It was farther learned that the beds in question had suffered in their history a change from true carbonate of lime to magnesian limestones or dolomites, and that the porosity of the limestones as attested by its holding gas, oil or salt water, was altogether dependent on this chemical change, beginning where it began and ending where it ceased. In other words, the dolomite corresponded exactly to the " oil sand " or " pay-streak " of the great petroliferous sand rocks in which we had hitherto found the principal stocks of oil and gas. The explorers of the new field all came from the old field and the identification referred to was universal. In composition the oil rock was in many instances found almost typical dolomite.

That the dolomite was not the original substance of the rock but a product of replacement was made evident from two lines of facts, namely: first, small insulated areas of true carbonate of lime that are sometimes found in the midst of dolomite districts; and, second, fragments of the oil rocks brought up by the explosion of torpedoes which show it to have been originally a crinoidal limestone. A stratum of this character must necessarily have been at the outset a true lime rock.

Farther, it was soon found that the productiveness of any portion of the field could be gaged with fair accuracy by knowing the thickness of the dolomite. It was also established that the areas within which the change had been accomplished were comparatively small and exceptional and that the great bulk of the Trenton limestone remained in its normal state, having a compo-

sition fairly represented in the following analysis (Trenton limestone—northern Michigan).

Carbonate of lime	82.00
Carbonate of magnesia	3.00
Insoluble residue	14.50

The composition of the dolomite, on the other hand, is shown in the following figures (Findlay gas rock).

Carbonate of lime	53.50
Carbonate of magnesia	43.05
Insoluble residue	2.96

Where the composition of the rock corresponded to the first table there was nothing to justify the application of the term oil rock to the Trenton limestone. It was seen that the dolomitic metamorphosis had taken place in only those portions of the limestone that were originally exceptionally pure in composition.

The conclusion seemed therefore justifiable that the storage quality of the Trenton limestone could be safely determined from its chemical composition. This conclusion applied to its great petroleum fields, namely, Ohio and Indiana, without qualification and holds good with respect to Michigan and Illinois as far as facts from these states have come in.

But subsequent observations and specially those to be recorded in the present report show that the conclusion must not be made general in its terms. It appears that the Trenton limestone holds considerable petroliferous accumulation in the form of natural gas in regions where no trace of the dolomitic replacement has occurred. In such districts it does not appear to be a true reservoir rock. It contains but little salt water and no continuity is apparent in such occurrences of the latter as are found. Nor does the water give indication of artesian pressure as in the oil fields of Ohio and Indiana.

Two principal modes in which gas is stored in rocks come into view in this connection. It is either stored in porous rocks, as sandstones, conglomerates or dolomites, in conjunction with other fluid, in which case it can be styled *reservoir gas*, or it is held in small spaces intervening between the leaves of shale or

limestone and then it may be designated as *shale gas*. The latter accumulations are quite likely to be found in pockets or distinct and unconnected areas that appear to be capriciously distributed.

Reservoir rocks follow geologic horizons closely. Salt water is found in such strata at certain points. Contiguous wells generally show approximate or exact equality of rock pressure and in them salt water rises to approximately the same level. The salt water is seen to be under artesian pressure.

Shale gas follows geologic horizons only in a general way. That the several bodies of gas or oil in a shale rock are not directly connected is evident from the fact that adjacent wells differ widely in the matter of their rock pressure. If salt water is found in them it occurs in small quantities only.

The discovery of the Findlay gas and oil seemed at first sight to turn almost the entire country into territory in which such production might reasonably enough be expected. The farther discovery of the dolomitic character of the really productive portion of the Trenton limestone seemed on the other hand to sharply restrict such possibilities. The last discoveries here to be described, do away to a considerable extent with the dolomitic limitations, and do something toward restoring the promise that the discovery in northwestern Ohio seemed at first to establish.

Section 1

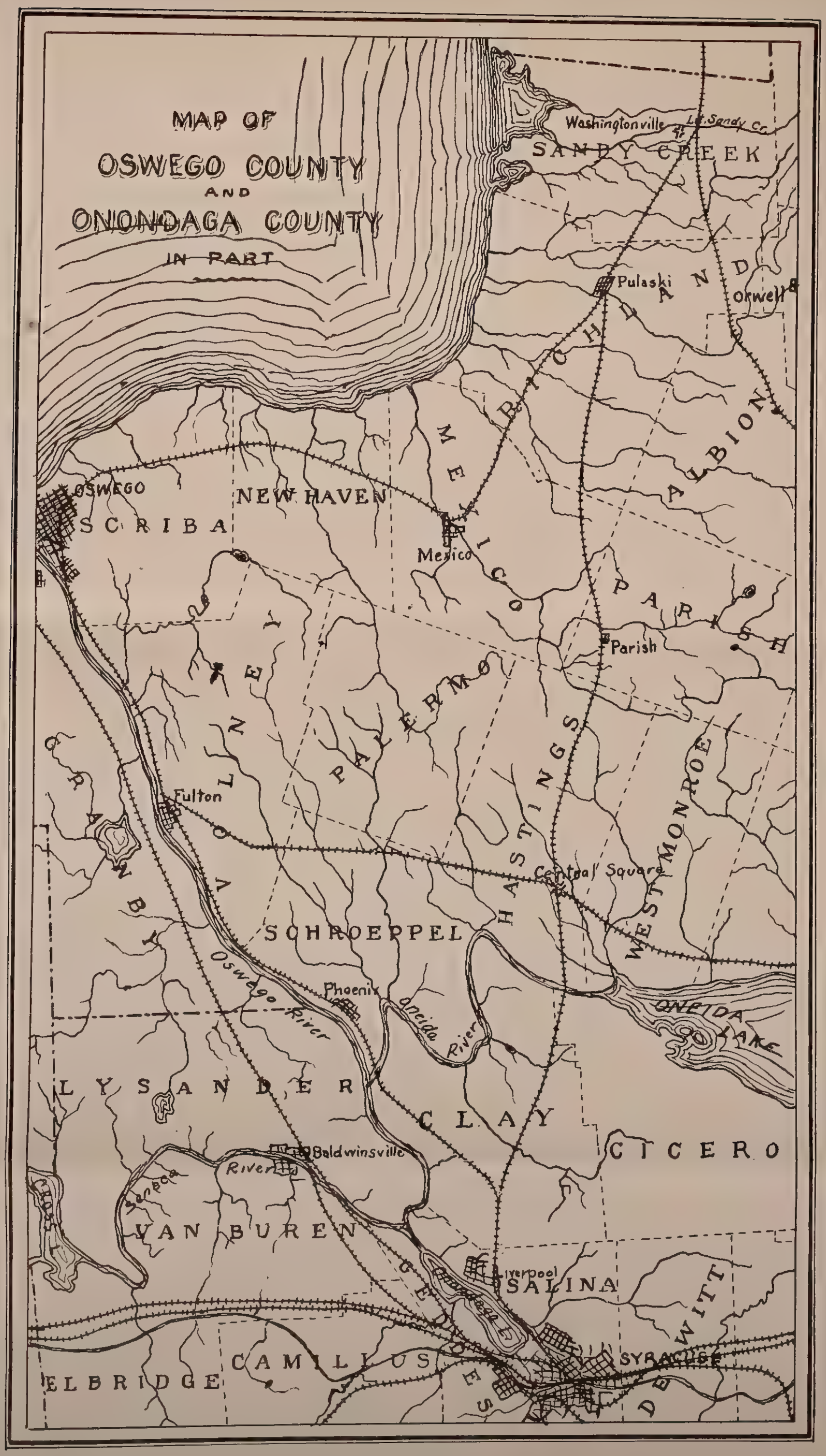
Oswego county

Among the earlier explorations for the petroliferous series in this county are those which have been made during the last 25 years and notably within the last five years at Fulton. Search was also begun in 1888 in Sandy Creek, and in Pulaski soon afterward.

The experience that has been gained at these different points will be briefly described in the order named and reference will afterward be made to other localities in the county that have carried forward exploration by the drill in the search for the same source of wealth.

Geologic scale of Oswego county. The lowest rock that takes part in forming the surface of the county is the Trenton limestone, but its part in this office is very small. It is confined to

LIMA
SYRACUSE
SALINA
Liverpool
Onondaga L.
ONONDAGA
CAMILLUS
ELBRIDGE
VAN BUREN
Seneca River
Cross L.


MAP OF
OSWEGO COUNTY
AND
ONONDAGA COUNTY
IN PART
Washingtonville
Lt. Sandy Cr.
SANDY CREEK
Pulaski
ORWELL
ALBION
MEXICO
Mexico
PARISH
Parish
NEW HAVEN
OSWEGO
SCRIBA
PALERMO
HASTINGS
WESTMONROE
Fulton
GRANBY
Central Square
SCHROEPPEL
Oswego River
Phoenix
Oneida River
ONEIDA LAKE
LYSANDER
CLAY
CICERO
Baldwinsville
Seneca River
VAN BUREN
Liverpool
SALINA
DEWITT
ELBRIDGE
CAMILLUS
SYRACUSE

a few square miles in Sandy Creek township and belongs to the uppermost beds of this great stratum.

Above the Trenton the Utica shale and the Hudson river series appear in the regular order over which in due succession to the southward the Medina sandstone is found. The latter is perhaps the best marked element in the geology of the county. Above the Medina, the Clinton in strong force and the Niagara in feeble development, are added in ribbon-like bands around the southern edge of the Medina. But little of the surface rock of Oswego county is to be credited to the Niagara.

The two principal formations are the Hudson river and Medina groups. Over the rock floor the glacial drift is spread in an irregular sheet. Strong morainic features are shown in several parts of the county.

The rocky floor is dissected by the rivers that cross the surface of the county, affording fine exposures of the geologic series. The Oswego river affords a good section of the Medina at Fulton while the Salmon river gives a splendid exposure of the Pulaski or Lorraine shales, and the Oswego sandstone is well shown near Lake Ontario. The Oswego is a fine and steady stream that carries the waters from the Finger lakes of central New York to Lake Ontario. It has a rapid fall but is always clear, the lakes acting as settling basins for the inflowing streams.

a *Fulton.* Explorations of a random sort called attention to this region as a possible source of gas more than twenty years ago. A well was sunk partly on such expectations, on the Van Buren farm in the valley of the Oswego river, four or five miles north of the village of Fulton, for the purpose of a test. Surface indications had long been noted here, consisting principally in the bubbling of gas through the water in boggy spots. The thin accumulations of bog iron ore that cover with an iridescent film the pools of standing water were possibly counted among the surface indications. The latter have no possible significance as leading to valuable stocks of gas or oil and the bubbling referred to can in many instances be well enough accounted for by the decomposition of vegetable matter which is always going on in such locations.

But a shaft 4 feet by 4 was sunk to the rock, which was reached at 18 feet. The drill then descended into the rock,

namely, the Medina sandstone, a few feet. The well filled with surface water, but gas still bubbled through it. The bubbles were caught in an inverted butter tub, the bottom of which had been provided with a jet from which the gas, in this case probably derived from the Medina sandstone, was lighted and burned. The experiment stopped at this point, but it had given its testimony and this took effect on the minds of some of the more observant members of the community.

Eight or ten years thereafter the excitement over the wonderful discovery at Findlay, O., recalled this experience and led to the formation of a company of some of the more enterprising citizens of Fulton. T. D. Lewis was president of the company and J. H. Case, secretary, and these two gentlemen took the leading part in all the subsequent development.

The company proceeded to make a thorough test at the same point where the first well was sunk, availing itself of the 18-foot excavation previously made by Mr Van Buren. The drillers employed were naturally skeptic as to finding gas in this unknown series and did not use any precaution as to the exclusion of fire, such as would have been employed in a known gas district. Light flows of gas were however reached at various horizons and one of them was accidentally ignited from the forge in the derrick. This latter structure took fire thus and was destroyed. The derrick was rebuilt and the work resumed. The several formations of the region already noted were passed in due order and the Trenton limestone was struck at a depth of between 1300 and 1400 feet. At 1727 feet, well down in the last named stratum, a gas vein of considerable volume and force was reached. Drilling was continued to the depth of 2020 feet, or about 650 feet below the top of the Trenton.

The company had demonstrated the presence of significant accumulations of inflammable gas in the rock foundations of Oswego county, but had found nothing thus far that could be turned to economic account in repaying them for the considerable outlay they had already made.

Meanwhile exploration was going forward around them. The villages of Sandy Creek and Pulaski had already found gas in the Trenton limestone and were proceeding to utilize it.

The experience of these villages suggested to the Fulton company a new line of action. To recover if possible the losses already incurred, Messrs Lewis and Case and other members of the old company organized a new company to drill wells and supply the village with the new fuel. The necessary franchise was obtained from the village council, options were taken on 14,000 acres of land lying near the village, and new wells were at once begun.

The first well was located on the Vogelsang farm about one and a half miles southeast of the village center. The section as reported was found as follows:

Medina sandstone	400 ft
Oswego sandstone and Pulaski shale	880
Utica shale	120
Trenton limestone, upper surface at	1400

These figures are approximate but they serve well as a general statement. This record was well supported by carefully saved samples of the drillings. The latter were kindly placed at the disposal of the survey by Mr Case, secretary. Gas was struck in the red Medina and at various points in the Trenton. The largest supply was reached at about 1700 feet, the rock pressure of which was enormous. To determine this point an expert was brought on from Bradford, Pa. He found the pressure to be 1240 pounds. The well was left to blow wide open for one hour and when the valve was closed, a pressure of 500 pounds was regained almost instantly, and in $10\frac{3}{4}$ minutes 1075 pounds were registered. On being deepened a few feet the pressure is said to have run up to 1525 pounds temporarily. The total depth of the well was not far from 2500 feet. The cost of drilling was $1.25 a foot. The well was at first tubed with two inch pipe, but the company was advised to replace this by three inch pipe. In making the change, a considerable body of very strong salt water, which had seeped in from various horizons outside the pipe was released and lay on the gas rock for 36 hours; but the original pressure was practically regained. As soon as gas was struck the company set about piping the town. The work was done in haste and in September 1895, 164 consumers were put on the line. But this demand proved beyond the capacity

of the single well. The supply was short and the pressure fell rapidly away.

Well no. 2 was located on the R. K. Sanford farm, which adjoined the Vogelsang farm. This well is about 2000 feet from well no. 1, and is due east of the village center. It was drilled to a depth of 2383 feet. Gas was found as in well no. 1 throughout the Trenton limestone and its yield was steady from the first. It was at once turned into the village line and relieved the demand of the consumers for the time being. Well no. 3 was located on the Palmer farm and was due south of the Sanford well. It was drilled about 2000 feet deep and furnished a moderate amount of gas.

By this time the fortunes of the company had come to be so promising in the eyes of the business world that competition was introduced. The first exhibition of it was made by a company that called itself the Oswego river gas company. A trial well was located and drilled in the river valley at the north end of the village, but it found very little gas and the company gave up the search with this one unsuccessful trial.

A more important attempt to establish itself in what was coming to be counted a new gas field was made by a body of petroleum producers and drillers called the Eastern oil company of Buffalo. This company secured a lease on the Hoff farm and located a well not more than 500 feet from well no. 1 of the Fulton company. The well proved successful and the Eastern oil company thereupon offered the home company one and a half dollars for every dollar it had invested in the field. The offer was declined and the Fulton company bought instead the new well and connected it with its village line. This well will be counted as no. 4.

Well no. 5 was located on the same farm on which the first well was drilled and but 600 feet distant from it. This well proved a complete failure. It was practically a dry-hole.

The company now had five wells on its village line, but it had taken on new consumers as it increased the number of its wells. From the first it had been obliged to overtax its entire supply. Each well had been drawn on to its full capacity, and the service of the company had for this reason always been unsatisfac-

tory. The amount of gas steadily declined and on the whole rather rapidly, till after a few months it was no longer a safe reliance in domestic heating. Its inexpressible convenience led many to retain the use of it in cooking stoves, even though great inconvenience attended the short supply. For light also it continued to be largely used. Things have gone on in about the same way from that day to this. The valves of all the wells are opened wide to the pipe line. Every foot of gas that can be secured has been in sharp demand from the beginning.

The company has expended more than $38,000 on its plant. It lost its one opportunity, not only to recoup itself but to secure a handsome reward for its courage and enterprise, when it rejected the offer of the Eastern oil company referred to above.

Its first wells cost about $3000 each, but after a little the company purchased a set of drilling tools and employed its own drillers. By this arrangement the cost of sinking wells was reduced to 60 cents a foot, or less than one half the price first paid.

The company has on hand a plant of fair equipment and character for the distribution of gas. The village is enterprising and prosperous and gaseous fuel has already established its reputation there so that a large and promising market is assured if only an adequate supply can be furnished.

It is refreshing to find that in the location of the wells above described there was no recognition of any "theories" whatever, as men engaged in this line of business love to style their crude speculations and vagaries. There was no "northeast line" on which they depended, but they had leased a considerable acreage convenient to the village and the wells were located on these tracts solely as commonplace and intelligible considerations dictated. It is true that after drilling several wells the company began to consider that a line joining two of the best must be the line of promise, but nothing came from this crude conclusion. In locating well no. 5 the company, in urgent need of gas to supply its clamorous customers, thought to avoid all risk of failure by locating the new well not only close to no. 1, which was then their best well, but even between it and another producing well. No. 5 was the only well of the list that was an absolutely dryhole!

In the Fulton wells gas was found all through the descent, namely, in the red Medina, in the Oswego sandstone, the Pulaski

shale and the Utica shale, and most of all in the Trenton limestone. In the latter formation it was confined to no particular horizon except that the greatest stock was found 200 to 300 feet below its uppermost bed. Each minor accumulation of gas seemed independent of the rest. In one well 22 distinct accessions were recorded in a single day.

Neither sandstone nor dolomite are found in the section and salt water was struck in but a single instance in the entire experience of the Fulton company. There is practically no difference in the conditions of the gas, whether found in the Utica shale or in the underlying Trenton limestone.

The rock pressure of the gas is, however, enormous. In shale gas this element generally ranges low, though pockets are occasionally found in all the shales in which high figures may be reached. 200 to 300 pounds make a limit that is not often overpassed. In the Fulton field the pressure ran up to the maximum of 1525 pounds, 1200 pounds being noted for some weeks in a single well.

The amount of gas from the wells of this series is comparatively small. As is well known, there is no relation between the rock pressure and the volume of wells. Wells of very small volume may reach very high figures in pressure. None of the Fulton wells proved themselves able to withstand the steady drain of the pipe line. Volume and pressure declined at once when the draft was put on them.

The question at once rises as to what use the gas discovery of Fulton could have been turned that would have brought profit to the company. As it is, a great deal of time and business energy and $40,000 in cash have been expended in the development and there is nothing whatever to show for it, so far as assets are concerned. The pipes buried in the earth could be recovered, it is true, but they could only be sold as junk. Practically the whole amount expended by the company can be counted as lost. Besides the expenditures named above a considerable amount has been expended in piping and equipping the dwellings of the town for the use of gas. Is there any possible use of the discovery that could have given to the community good returns in money value?

A well could have been drilled at public expense that would have furnished an ample stock of gas for lighting the streets and residences of the village for several years. So far as the streets are concerned the light would be so far inferior to the electric light in brilliancy that the change would not have been welcome to the people, even though a great saving in expenditure could be assured thereby.

Furthermore the system of distribution by which gas can be used for illuminating is already established in the village under private ownership. There could be no true economy in duplicating this system, and it would probably be impossible to secure the existing plant for the actual amount used in its establishment. If the coast were clear and electric light and gas companies were not already in the field a profitable use of the gas discovery could have been made by the village in the direction named.

For one use the way was open, namely, for domestic use, and that was naturally the line of service adopted by the new company, and in which it has lost its investment. Could this loss have been avoided? In the light of present knowledge the company can easily see how it might have followed a course that would have led to financial success instead of failure. If but one tenth the outlay in piping the town had been incurred and only one or two streets had been opened for this purpose and 20 or at most 40 consumers had been supplied with fuel, instead of 164 (the number on the line when the first well was finished) and if the gas had been sold by meter instead of by mixer rates, at a price commensurate with its value, the results might have been altogether different. Under these circumstances the wells would not have been overdrawn. Opportunities for resting them would have been found, and Fulton would still be rejoicing in a limited supply of the best fuel of the world.

The villages of Oswego county are not the only villages of the state to find natural gas within their precincts. Many discoveries of this kind are likely to be made in days to come. To learn by one's own mistakes is always hard and costly, but it seems possible so to record the facts in a case like that now under consideration that they can serve the interests of other communities that may find themselves in the same general situation.

No disinterested person with adequate knowledge of the experience that has been so abundantly accumulated within the last 15 years would advise such a course as the Fulton company pursued. It is possible to indicate a policy that would have returned the money invested and would have given to some hundreds of people the inexpressible advantages of gaseous fuel for several years.

Still another possible use of natural gas, viz, manufacturing use, is reserved for discussion in connection with the experience of other localities.

b *Sandy Creek.* The village of Sandy Creek is located in the township of the same name in the northwest corner of Oswego county. There are two sections of the village with an interval of about one mile between them. They are known as Sandy Creek and Lacona, and in earlier times went under the name of Washingtonville.

By a disastrous fire that visited the village 10 or 12 years ago, its one manufacturing interest, viz, a large tannery, was destroyed and nothing was found to take its place. The more enterprising of its citizens felt that something must be done to arrest its discouragement and decay.

The Trenton limestone excitement that began with the experience at Findlay, O., in 1884, was already under way and, as surface indications, probably of the bog gas variety already referred to, were found here, and as drilling though unsuccessful had been undertaken at Watertown, in the county north, it was determined in 1888 that a test of the rock should be made here. A company was formed under the name of the Sandy Creek oil and gas company, limited. It comprised the best citizens of the village and took in also many of the more intelligent farmers of the neighborhood. The capital of the company was placed at $5000 and the stock was sold in shares of $10 each. There was a large number of subscribers and the burdens of all were light. O. R. Earl was elected president and Gilbert N. Harding secretary.

The company bought the drilling outfit that had just been in unsuccessful operation at Watertown. It also entered on the leasing of land on quite a large scale. At first an annual rental of $5 an acre was paid till drilling should be undertaken on the

premises. For each completed well, if successful, a rental of $25 a year was to be paid. About 13,000 acres were taken up, but the rate of rental was soon reduced to $1 an acre annually and has since been cut down to still smaller figures.

The first well was located in the valley of Sandy Creek between the two villages. The rock at this point is overlaid with only a very shallow covering of drift. A little gas was struck when the rock had been penetrated a few hundred feet, but presently the drilling tools got fast and the company, being dissatisfied with the contractor, shut down the work. The next year, 1889, operations were resumed under a new contractor. The tools were got free and the drilling was carried deeper. More gas was struck as they descended but the rock pressure was comparatively feeble, reaching only 80 pounds to the square inch. Several pockets of gas were struck as the drill went down, in which much higher pressure was shown. At times water froze around the tools, owing to the rapid expansion of the released gas. The village was forthwith piped and the utilization of the gas was begun in the same year.

The use of the new fuel has gone forward without interruption to the present time and this first well has played an important part in the supply. In August 1897, its pressure was found to be 60 pounds, a fall of but 20 pounds in eight years of large but not constant use. Its pressure has sometimes been higher than when the well was first opened, suggestive of the idea that it may be borrowing gas from other areas of rock near by. The highest figure that has been noted is 100 pounds. When the well is steadily used the pressure declines, but by resting, it is usually restored. This well has proved an excellent supply. It is good for 30,000 to 40,000 feet a day. The company has drilled 18 wells in all, and so far has discarded but one as without value. Salt water has been found in but two of the number; in one of them at 900 feet and in another at 35 feet below the top of the Trenton.

Well no. 2 is located one half mile down the creek. It was drilled to a depth of 1080 feet. In its early history it met with a misfortune by which its value has been impaired. The casing collapsed and the well was flooded with fresh water for some time. It has not proved as valuable a source of gas on this ac-

count as no. 1. Well no. 3 was located one half mile directly east of no. 2. It was drilled to a depth of 1100 feet and proved a fairly successful well. It has been on the line for the last seven years. Well no. 4 was also drilled to a depth of 1000 feet, its location being one half mile directly east of no. 1. It had 40 pounds of rock pressure when completed. It was never tubed but was packed in the casing. It holds its original pressure, after being shut off from the line for a few weeks.

Well no. 5 is one of the two deep wells of the company, having been drilled to a depth of 1265 feet. It has proved a fair source of gas. Its initial rock pressure was 50 pounds. Under the steady draft of the pipe line in winter the pressure falls to 25 or even to 20 pounds, but when rested a few weeks it regains its old figure. Well no. 6 is three fourths of a mile south of no. 1. It is also a fair producer. Its initial pressure was 70 pounds. Well no. 7 is one and a half miles south of no. 3 on the Pulaski road. At 900 feet salt water in large amount was struck at the level where gas is found in many other wells and both products were delivered by the tubing at the same time. Its rock pressure was 250 pounds. Its usefulness was interfered with by the presence of the water, though, of course, a separation of the products is possible.

Well no. 8, one half mile southeast of the village center, had an initial rock pressure of 40 pounds. Well no. 9, one half mile east of the village center, had 105 pounds initial pressure. Well no. 10 is one half mile east of no. 9. It was counted a good well when completed, but it does not seem to have the staying properties of many of the other wells. It is obviously losing ground under use, its pressure not rising above 20 pounds at the date of observation in 1897. Well no. 11 is three quarters of a mile south of no. 1. It met with bad fortune at the outset. A pocket of gas was struck which was under a high pressure. The drilling tools were blown out of the well and the cable cut by the flying chips. The well was packed in the Trenton limestone instead of in the overlying shale. It has never been equal in production to the best wells of the company. At the end of one and one half years of use it shows, however, a rock pressure of 50 pounds. Well no. 12 is located in the valley of Sandy Creek,

one half mile northwest of no. 2. It has proved an average producer and now holds a pressure of 70 pounds.

Well no. 13 was one half mile west of no. 2. It has proved a fair average of the series to which it belongs, and holds a rock pressure of 70 pounds while in use. Well no. 14, one half mile northeast of the village center, is but 900 feet deep. It reached the top of the Trenton at a depth of 600 feet. A pocket of gas was struck, the tools were lost, and the casing blown out. The well has proved a good one but is losing volume at the present time. Well no. 15 is 1000 feet deep. It is located one half mile north of no. 1. It has proved one of the best wells of the series. It has been an important contributor to the supply of the line for two years, and when rested, promptly recovers at least a large part of its original pressure. Well no. 16 is 1000 feet deep. It reached the Trenton at 400 feet and has proved a fair well. Well no. 17 has recently been completed. It shows a rock pressure of 100 pounds. It reached the Trenton at 385 feet, and shows a good volume of gas.

One well that was drilled by the company produced so small a quantity of gas that it was never connected with the pipe line. It would have completed the list of 18 wells, above given.

Throughout this region the drift is shallow, not more than 10 to 25 feet of drive pipe having been called for in any instance, and in the valley locations the superficial deposits are often less than five feet.

The wells are all located within a circle two miles in diameter, the farm lands contiguous to the village having been generally leased for this purpose. They do not appear to draw on each other, and probably the number could be considerably increased within the limits named.

The uppermost member of the rock series is the Pulaski shales, under which the Utica shales are found. The latter are 250 to 300 feet in thickness. The thickness of the Pulaski shale varies greatly according to the altitude of the surface, which declines rapidly to the westward. In some instances there is less than 100 feet to be credited to this division. The Trenton limestone, when shallowest is found at 385 feet, and when most deeply buried, at 600 feet. The wells are generally finished at 1000 feet. The only deeper wells were carried down to 1200 and 1265

feet respectively, but no advantage was gained by drilling the last 200 feet. In the 1200 foot well, the last thing struck was a very gritty rock, but underneath it limestone again appeared.

There is no definite relation between the gas volume and the rock pressure of a well. A well with low pressure may contribute to the line steadily and well through a long period. Of the daily production or capacity of the wells no record has been kept, but the superintendent counts 100,000 cubic feet as the unobstructed production of a good well for 24 hours.

Gas is not found in definite horizons, but is mostly confined to the Trenton limestone. It is likely to be found in small amounts when the drill has sunk but five or ten feet into this formation. From the surface downward till 600 feet of the series have been traversed, there are innumerable accessions of gas, the best of the flows being found in the lower part of the formation.

The dip of this stratum is strongest to the southward. On a southwest line of six miles between Sandy Creek and Pulaski the surface of the Trenton falls 150 feet, or 25 feet to the mile.

In the last year the metered output showed the production of the wells to be 17,280,000 cubic feet of gas. Probably enough gas was used or lost outside of the meters to make the total 18,000,000 feet.

The gas is sold at the nominal price of 35 cents a thousand, but a discount of 10 cents is allowed for prompt payment of bills, so that in reality the price is 25 cents a thousand cubic feet.

The use of the gas is exclusively confined to house service. In the severest weather there is occasionally a temporary shortage in the morning hours, as the mains are but three inch pipes, but on the whole the supply is eminently satisfactory to all the patrons of the line. For the last three years the service has been nearly perfect.

In the location of the wells the aim has been to keep them approximately one half mile apart, but no theory whatever has affected the location and no "lines" or "belts" have been developed by the experience of the company thus far. In this respect, as in all others, the gas conforms exactly to the characters of shale gas.

It is of vital importance to use the wells alternately. A well kept on the line for months without relief loses pressure and volume, but a few weeks rest is generally effective in restoring both.

The original capital stock of the company, as has been said, was $5000, but this amount has since been raised to $15,000 and the company has considerable debt besides, but it is paying its obligations as far as possible out of its income, which latter is about $4500 a year, and all of which is used on the plant. No one looks for any return of the amount originally invested.

The experience of this village has been highly satisfactory. The community has now enjoyed for nine years the inexpressible convenience and luxury of natural gas for fuel and light. To every household using it there has been a distinct increase of the comforts of life, and a distinct diminution of its discomforts. There has also been for all stockholders in the company an annual reduction of the cost of fuel and light that will go far toward repaying them for the original investment.

It is hard to see how the fortunes of the village could have been improved by any different management. All the work has been carried on soberly and sagaciously and without illusions or self-deception or "booms" of any sort.

The example of Sandy Creek in its use of natural gas may well be taken as a model for all communities similarly circumstanced. The character of the gas as shale gas is unmistakably displayed in the record above given. The lack of definite horizons, the frequent occurrence of pockets, the absence of salt water, the want of agreement as to rock pressure in the various wells, even in those nearest to each other, are all marks that admit of but one interpretation.

c *Pulaski.* This village was inspired to undertake the search for natural gas by the successful experience of the neighboring village of Sandy Creek, above described. It had also grounds of encouragement of its own. "Surface indications" had long been known in the form of escaping gas. The best known locality was a small but picturesque island in the valley of the Salmon river, adjoining the corporation. Many outcrops of the rocks occur on this island, and from some of the natural joints it has long been known that gas was escaping and could be

lighted. The island is used as a park and is known as Island grove. The surface rocks of the region belong to the lower portions of the Hudson river series. One of the names assigned to this division by the New York state geologists in their first system of nomenclature was drawn from this very locality, namely, the Pulaski shale. Another name proposed for the same section was the Lorraine shale. This designation was drawn from the fine exposures of this rock in the town of Lorraine, Jefferson co. where the series has been dissected by the gorge of Sandy Creek.

The Salmon river section of the Pulaski shale is 40 to 50 feet in thickness, within the village limits. It is made up principally of sandy and calcareous shales in which the characteristic fossils of the formation are well and abundantly displayed. There is very little material in the section that can endure exposure to the weather. Occasionally a layer is found that does not immediately disintegrate and such are used to a considerable extent in unimportant masonry.

Farther up the stream a much longer and finer section is to be seen at the falls of the Salmon river in Orwell township. The Medina sandstone occurs in force in this township, and possibly the Oswego sandstone also. The sandstone is best seen in what are called the Grindstone quarries.

The mantle of drift is nowhere of great thickness and it adapts itself in a general way to the topography of the rocky floor on which it was deposited. The general level of the town is somewhat more than 100 feet above the level of Lake Ontario.

A company was organized in the spring of 1891 made up of public spirited citizens. Louis J. Clark, president of the First national bank, was made president of the exploring company.

The first well was located on Mill street. At a depth of 559 feet a flow of salt water and gas was reached. The water was thrown above the derrick in a milky shower which continued for about 24 hours. At 980 feet a blower of gas of great force was struck, in the night. It not only lifted the drilling tools but carried out the casing and tubing as well and packed the cable so closely in the casing that it was necessary to use an axe on the latter in getting it free. The salt water that had been found at a higher horizon accumulated on the lower gas rock and nearly ruined its production.

The well was, however, recased and retubed and it still supplies an insignificant amount of gas, barely enough for the demands of the single residence with which it is connected.

A second well was at once located about 300 feet east of the original location. In this well no salt water was encountered and at 980 feet, the horizon of the pocket in well no. 1, only a small puff of gas was found. The drill was kept at work till a depth of 1500 to 1600 feet was reached. Small additions of gas were made from day to day as the tools descended, but the total yield was small, only enough, as the event proved, to supply the single family of the farm on which the well was drilled. This well was cased at 125 feet, but not quite low enough to exclude the fresh water altogether. It was found necessary to blow out the well every few months, and in wet seasons, oftener. The drill was stopped in this well at a depth of between 1500 and 1600 feet and, as was learned by later experience, had been carried almost to the granite.

By the drilling of these two wells, it had been demonstrated that gas was to be found in the rocks underlying Pulaski, but there was naturally some hesitation on the part of the company in undertaking the additional expense required for the utilization of its discovery. At this point one member of the company, namely, Mr Charles Tollner, grew impatient with the delay and determined to carry the work forward at his own expense. He accordingly bought out the stock and franchises of the old company and proceeded forthwith to pipe the village for the use of gas, even in advance of farther tests. He took drilling options on a large area, (15 to 20,000 acres) surrounding the village. The limit of the option was 10 years and for every well accepted, $50 a year was to be paid.

Mr Tollner was a manufacturer who had established a large and successful business in Pulaski. He had accumulated a handsome fortune for this region by his energy and sagacity and was beyond question the leading business man of the community. He had something of the idealistic temperament as well and the idea of turning to practical service a stock of power buried beneath the surface, of which he was one of the discoverers, appealed strongly to his imagination.

In piping the village no expense was spared that was counted necessary to the most satisfactory service. In the size of the pipe, the quality of the connections, the regulators, etc. the best rather than the cheapest were in all cases selected.

It will be remembered that though two wells had been already drilled, there was not a large quantity of gas that could be depended on. The first well was a failure and the second well imperfectly cased, but both had proved the region to be gas-producing territory. To fill the pipes now laid in the streets of Pulaski new wells must be drilled, and Mr Tollner next set about this part of the work. He undertook it in the same spirit in which he carried on the piping of the town, paying full price for all the work, and neglecting to avail himself of the economies which competition would have insured.

When his first well was completed, the gas found in it was at once turned into the village lines and utilized by householders who had prepared their dwellings for it.

Mr Tollner drilled 20 wells and bought one that had been drilled by outside parties (the Eastern oil co. of Buffalo) within the territory which he occupied. The driller in charge of all of his later work was Mr W. O. Potter who came in from the Pennsylvania oil fields. From him and from other drillers and from the samples of drillings saved in the process of the work, the following general section can be taken as embodying the principal facts as to the Pulaski wells. The same section will serve for much of Oswego county.

Pleistocene	Drift	0– 96	ft
Ordovician	Pulaski shale	200– 250	
	Utica shale	100– 250	
	Trenton limestone	600	
	Calciferous	200	
Cambrian	Greenish sand (Potsdam?)	10– 40	
	Black limestone (called "black granite" by some drillers)	20– 40	
	Greenish sand	5– 10	
Archaean	Red (orthoclase) granite struck at	1400–1500	

The Trenton limestone is struck in this field at an average depth of 550 feet. Most of the Pulaski wells are drilled to a depth of 1000 feet, but enough have been carried to the granite

to establish the general order of the several strata that underlie the Trenton limestone. The first gas is sometimes found in the Pulaski wells only a few feet below the top of the Trenton limestone. Beginning at 20 feet in this formation, accessions are often found every 10 to 15 feet for the first 100 or 200 feet. This is called the first vein. Below this depth, larger and more persistent veins are found and they are liable to be struck through much of the remaining portion of the Trenton section. This is called the second vein. It is generally reported at about 1000 feet.

The initial rock pressure of the Pulaski wells ranges between 165 and 650 pounds. But a single example has been noted in which the highest figure was reached. The pressures of the several wells when first completed were as follows: 170 lb., 250 lb., 600 lb., 400 lb., unproductive, 325 lb., 400 lb., 165 lb., 250 lb., 400 lb., 390 lb., 600 lb., 400 lb., 170 lb., 650 lb., 600 lb., 500 lb., 170 lb.

No figures were obtained as to the daily gas production of a new well, and no opportunities for measurement were found, but a few tens of thousands of cubic feet will cover the production of all except the very largest wells.

A brief account of the Tollner wells, 20 in number, will here be given.

Well no. 1 was located on Island grove already referred to, of which Mr Tollner was the owner. This well was begun on July 4, 1893. The well was drilled by O'Donnell & Rick, experienced Pennsylvania drillers. The Trenton was struck at 550 feet. The largest gas vein was not reached till a depth of 1050 feet had been drilled. A rock pressure of 170 pounds was observed at this point. The well was not carried to a greater depth.

Well no. 2 was located one half mile northeast of no. 1. It was drilled to a depth of 1100 feet, when a pressure of 225 pounds was reached. Two main veins of gas were found, one at 800 feet and the other at 1000 feet. Of these veins the last was the stronger. The Trenton limestone at the point where the drill was stopped, was black, a phase which it takes on at the typical locality, Trenton Falls.

Well no. 3 was located on North street, one half mile due north of well no. 1. It proved much more productive than either of its predecessors. Its first strong vein was found at 700 feet

and its second at 1100 feet. It was drilled to 1150 feet in depth. Five hours after it was packed it showed a rock pressure of 500 pounds, and in three days 600 pounds were registered. When the gas was turned into the village line there was some water in the pipe which was frozen by the rapid expansion of the gas. In thawing the pipe fire was accidentally communicated to the well, and a considerable demonstration followed. It was some time before the well was again brought under control. Its rock pressure never rose above 400 pounds thereafter. In the winter of 1896-97 the pressure was drawn down to 35 pounds, but though subjected to a long-continued and steady draft, it did not fall below this figure. Well no. 4 is located one half mile northwest of no. 1. At 650 feet a powerful gas vein was struck. The cable was cut by flying chips and the drilling tools were lost. The gas showed a rock pressure of 400 pounds and the well was not drilled deeper. In the winter of 1896-97 the pressure did not fall below 40 pounds. Well no. 5, located to the southeast of no. 1 was drilled to a depth of 1200 feet but only an insignificant amount of gas was found there. It was the first example of a dry hole in this field. Wells of this character are popularly and jocularly known here as "post-holes." If the well had been tubed, possibly gas enough for a single residence could have been obtained from it.

Well no. 6 is located one and one half miles from no. 1, and directly north of the village center. At 700 feet, gas enough for the drilling engine was struck, and at 1150 feet a powerful vein was found. It raised the tubing, but the clamps struck the casing and thus were stopped there. The tools were left in the well, which was packed at 600 feet. 300 pounds rock pressure was noted when the well was renewed. Well no. 7 is three quarters of a mile due north of no. 6. At 650 feet it found gas enough for the boiler of the drilling engine. A second vein was reached at 1000 feet and this grew steadily stronger till 1150 feet was reached, when a pressure of 450 pounds was registered. Under steady use it is drawn down to 50 pounds, but the impression among those who have the care of the line is that no. 7 supplies a larger volume than any other well of the field. Its production has been estimated at 100,000 cubic feet a day, but the grounds on which the estimate is based are not understood.

Well no. 8 is seven eighths of a mile due north of the village. It is 1200 feet deep and has furnished but little to the pipe line. Gas was found at 650 feet, but not enough for the boiler of the drilling engine. A second vein was struck at 1100 feet, the pressure of which rose to 165 pounds. Well no. 9 proved the second dry hole of the series. It is located three eighths of a mile north of no. 3.

Well no. 10 was drilled by the Eastern oil co. of Buffalo and was bought in by Mr Tollner. It is one half mile north of no. 4. The first important vein of gas in this well was struck at 600 feet. The well was finished at 1050 feet. It behaves differently from any other well of the series in respect to rock pressure. On one day it will show 125 pounds, and on another, perhaps but 25 pounds, and there is nothing apparent in the condition to explain this difference. Well no. 11 is three fourths of a mile north of no. 4. At 650 feet, gas enough for the boiler was found. At 1000 feet an uncommonly good vein was struck. This well showed a pressure of 400 pounds, after being shut in four hours.

Well no. 12 was drilled to the granite, which was struck at 1425 feet. It also was destitute of gas, the third in the series thus far. At 180 feet in the descent a strong vein of slightly mineralized water was struck. It continues to flow from the well mouth as a spring. Well no. 13 is located on the bank of Salmon river near the lake, three fourths of a mile from no. 11, with the record of which it is in close agreement. In fact, the records of the two wells as to horizon, pressure and apparent volume are nearly identical. They rise and fall in pressure together and it would appear that they have some underground connection. They are both among the good wells of the line, making an important contribution to the supply of winter gas to the town. They are rested by being shut off from the line five months in summer.

Well no. 14 is the fourth dry hole out of the 20 wells drilled by Mr Tollner. It is 1300 feet deep and no account whatever is taken of it. Well no. 15 is three eighths of a mile west of no. 4. It lies between nos. 4 and 11. It was drilled in 1895. The first gas was struck at 600 feet and the last at 1100 feet. It shows a pressure of 400 pounds and apparently has good volume. Well no. 16 is another of the good wells of the circuit.

It showed a pressure of 600 pounds when the lower gas vein was struck at 1175 feet. Well no. 17 is found to be affected by a considerable dip of the strata to the westward. It is a half mile west of no. 16 and is 1200 feet deep. The main gas veins were struck at 700 and 1175 feet. The lower portion of the Trenton limestone was black, as in one case previously reported. This well shows 170 pounds maximum pressure, but its minimum pressure thus far has been 130 pounds, even under steady use.

Well no. 18 is three eighths of a mile west of no. 17. It is one of the good wells of the series, holding its pressure under severe use better than any other well of the line. Its maximum pressure is 650 pounds, and at the end of the winter it does not fall below 260 pounds. The first gas was found at 650 feet and at 1175 feet the volume and pressure were so satisfactory that drilling was suspended there. Well no. 19 is three eighths of a mile still farther west than no. 18. It is 1150 feet deep and got its first gas at 675 feet or 25 feet lower than no. 18. Its full pressure is 600 pounds and thus far it has never been reduced below 300 pounds.

Well no. 20 is still farther west three fourths of a mile beyond no. 19 and on the lake shore. The westward dip of the strata carries all the horizons a little lower. The well has good volume and good pressure. It is 1325 feet deep and obtained its last flow of gas at 1300 feet. It has a final pressure of 500 pounds and after being shut off the line continues to gain for a full month. It is a good gas producer as compared with the other wells with which it is associated. Well no. 21 is located near the original group of wells east of the village. It is situated northeast of no. 2. The Trenton limestone was struck at 575 feet and at 650 feet a blower of great force was struck. The well was carried to a depth of 1075 feet but all of the lower portion of the Trenton proved unproductive, no second vein of gas being reached.

The price for drilling these wells was $1 a foot. It could have been considerably reduced by inviting competition. Of the 20 wells drilled by Mr Tollner, four were dry holes, as has been shown in the preceding records.

The wells farthest from town are four miles distant. The nearest are just outside or even within the corporate limits. The

plan pursued has been to keep the nearest wells for winter supply, but various causes come in to modify this practice. Every well is expected to give at least one month's service in a year.

The gas is used exclusively for domestic purposes and is all sold by meter at the rate of 25 cents a thousand feet. There are approximately 250 residences depending on the line for fuel and in many cases for artificial light also. The supply has been from the first adequate and satisfactory, barring the severest mornings of the winter, when the pipes are liable to be overtaxed for a few hours. Gas has displaced other fuel in town largely. The price of wood has fallen from $2 to $1.25 a cord.

There are four regulators on the system, set at the four cardinal points. The north regulator receives the gas of four wells; the south and the east regulators each receive the gas of two wells; the west regulator takes the gas from all the western wells which include the most productive of the series.

The amount of gas consumed in each of the winter months is about 4,000,000 cubic feet or an average of 133,333 cubic feet a day. There are about 300 meters in use. The amount of gas paid for from Aug. 1, 1895, to Aug. 1, 1896, was 25,000,000 cubic feet. This gas was all supplied by the first 11 wells. For the year 1896-97, the amount of gas used was 35,000,000 cubic feet.

The price of the gas, 25 cents a thousand, is certainly much below its intrinsic value. It is cheaper, all things considered, than wood at $1.25 a cord, but the people had no reason to complain when they were obliged to pay $2 a cord and be at the expense of cutting it besides. Counted on this basis, the price should be 35 cents a thousand.

Mr Charles Tollner, the founder of the Pulaski plant, died in the summer of 1897. He has invested between $50,000 and $60,000 in this business. Some of his heirs declare that the investment from a financial point of view was a mistake. The gross income, it is true, is a little more than 10% on the money invested. But new wells are required to maintain the supply, and supervision, rentals, repairs and other necessary expenses leave nothing to be returned to the Tollner estate. If the price of the gas were increased 50% or 100% there would be a possibility of some return as interest on the money invested, but even then it would be necessary to face the fact that the cost of maintaining the plant

would be constantly increased and that at no very distant day the gas supply will be exhausted. When this time comes, the $60,000 invested in the field will be an almost total loss. As long as the supply is maintained at present prices, the Tollner estate may be considered as donating the interest of $60,000 annually toward paying the fuel bills of two or three hundred of the most prosperous citizens of Pulaski. It is deemed proper to call attention to these points, for the example and experience of Mr Tollner are often so quoted as to make his case seem wise and sagacious from a business point of view.

Other deep wells have been drilled in various parts of the county, under the impulse that has already been described. No results of economic interest have been reached by any of these explorations but geology finds something of value and interest in their record.

d *The Stillwater well.* A well was drilled in 1897 in the southeastern part of Orwell township. It was located on the west bank of the Stillwater creek, by which name the Salmon river is known above the falls. The well site is higher than Pulaski by a little more than 500 feet. The record of the well is as follows:

Drive pipe	37 ft
Sand and shale, (cased at this depth)	255
Oswego sandstone	90
Pulaski shale	530
Utica shale	113
Trenton limestone, struck at	925
White Trenton	300
Dark Trenton	370
Sand and shales	40
Sand, green and white	25
Black limestone	6
Red and white sandstone, calcareous	18
Granite, struck at	1 697

The granite was drilled into for five feet. This record shows but 772 feet between the top of the Trenton and the granite. In other sections 100 feet more has been found for the same interval.

The record below the Trenton in this well was specially interesting and valuable. Good sized fragments of the greenish white sandstone and also of the black limestone were brought up by the sand pump. The limestone was examined microscopically by Dr J. M. Clarke of Albany, who reports it as a true brecciated limestone carrying a little phosphate of lime. Fragments of shells of Obolella and Lingulella are recognizable in it and, more doubtfully, fragments of trilobite crusts. The fossils named agree with the stratigraphic position of the limestone, which is of Cambrian age and not far removed from the Potsdam sandstone. Probably the sandstone overlying it belongs to the last named formation.

At 45 feet in the Trenton, namely, at 970 feet, a light vein of gas was struck and a slight increase was noted also at 1045 feet, but beyond this there was no sign. This well was drilled under the direction and inspiration of C. W. Vroman, who has had much experience in the oil fields of Pennsylvania and Ohio and who has been prominent from the first in the test wells of central and northern New York. The Orwell well was located in part on a theory. A little amber oil is said to have been found, emerging from a bed of sand which is the source of a spring in the township of Greig, Lewis co. The oil was believed by those who reported it to be native to the location. The sandy drift was 40 feet thick, but whether derived from a sandstone disintegrated in place or from glacial deposits has not been made clear. The first rock formation beneath this sand is the granite of the region. A well was drilled here over 800 feet into the granite.

This little show of oil has made a great impression on several of the drillers who have been at work in this region and has led to the spending of many thousands of dollars. It will scarcely be believed, but such is the fact, that this light surface indication, which may be the result of a deliberate attempt to deceive and not natural at all, has been counted the evidence of a new geologic horizon of oil which it may be worth our while to investigate. Lines have been drawn on maps of varying scale and having indefinite degrees of inaccuracy, connecting this little spring in the North woods with the great oil fields of Pennsylvania and a charm has by some been supposed to lie in points

that are found on such a line, when its direction is half way between north and east.

The geologic absurdity of all this it is impossible to overstate, but such is the natural desire of the mind for rational guidance, or at least for the semblance of such guidance, instead of mere guess work, that men intelligent enough in other respects have taken up the 45° and 22½° lines as if they could give a clew to the accumulations of oil all the world over.

The fact that a sand rock overlying the granite was struck in several wells of the county and that in one of these to be described hereafter it held a considerable supply of gas, is also to be taken into account. The location of the Orwell well is best explained by the statement of these facts.

The Potsdam sandstone is unquestionably a widespread stratum in the underground stratigraphy of this portion of New York, but thus far no petroleum has been reported in any of its unmistakable occurrences.

The Stillwater well gave new data for the measurement of the dip of the strata. The descent of the Trenton from this well to Pulaski is about 12½ feet to the mile in a due west direction. The southward element of the dip is much stronger.

e *Mexico.* Another deep well was drilled at Mexico, a dozen miles southwest of Pulaski. The Trenton was found at 1027 feet, and the well was carried to granite at something less than 2000 feet. Small gas veins were struck at 1300 and 1400 feet but no economic value was attached to the discovery.

f *Parish.* An immensely interesting record has been obtained from drilling in this town. A deep well was put down here by the Eastern oil co. of Buffalo, the operations of which have been before noted. The management of the work was in the hands of Charles W. Vroman, who later drilled the Stillwater well, already described. Drilling was begun on the Parish well in 1895, inspired by the experience at Sandy Creek and Pulaski. The show of oil at Greig is said to have figured also in this location. Some of the operators who were making explorations in this region were sanguine that oil would somewhere be found in a stratum that had proved to be so important a gas rock as the Trenton limestone. Such a conclusion seemed warranted by experience, for in all the great fields every good gas rock has at

some point been found to be a repository of oil as well. It does not, however, follow that there can be no exceptions to this general rule.

The first well was located on the Carley farm, two and a half miles southeast of the village of Parish. It was drilled to a depth of 2000 feet and but very little gas was found. The depth at which the Trenton was struck is uncertain, but at 2000 feet the company that was carrying forward the work proposed to abandon the test, but the derrick was left standing. Meanwhile, another well had been drilled a few miles west at Central Square, in Hastings township, and the drill had been carried down to the granite, which was reached at 2450 feet. Between the Trenton limestone and the granite an interval of 150 feet was reported. The sandstone already named (Potsdam) was found in this interval and to drillers familiar with the Pennsylvania oil sands, it seemed to belong to the same class. Its clean and open grain was adapted to ample storage of water, oil or gas and these facts, taken in connection with the discovery of oil in Lewis county, before described, were thought by experienced oil producers to justify a farther search in this neighborhood. This deep sand was likened to the McDonald sand of western Pennsylvania and great expectations were built on the resemblance.

A few weeks after the first well at Parish was abandoned one of these sanguine operators returned to the village and offered to drill to the granite if citizens would cooperate. $400 was subscribed by the people and the drill was again set in motion. The hole was deepened 120 feet, carrying its depth to 2140–50 feet, when granite was reached. The latter was penetrated to a depth of 7 feet. In passing through the interval below the Trenton limestone, the same series previously reported, consisting mainly of Potsdam sandstone, was found.

The most interesting fact in connection with this well remains to be stated. In the sandstone, which is about 50 feet thick, in the lower half of the interval, a vein of gas was struck. The gas showed considerable force and pressure. Though the well was imperfectly packed, the gage put on it registered a pressure of 340 pounds. This gas seemed to the drillers to differ in several marked particulars from the Trenton gas, with which they had become familiar. It had, as they reported, a different

odor, resembling more that of Pennsylvania gas. It burned with a much redder flame and deposited carbon or lampblack more abundantly. In fact, it seemed particularly rich in this last substance.

In my visit to the well in 1897, it was impossible to verify all these observations. The odor of the gas did not seem to differ in a marked way from that of Pulaski gas, and certainly did not suggest Pennsylvania gas. The redder flame of its burning was, however, recognizable, and with this fact the greater deposition of carbon could readily be seen to agree. It was not found practicable to attach a pressure gage, but the testimony as to the fact of the original figure was direct, and there seemed no reason to call it in question.

After the well had been drilled to its full depth, a small torpedo was exploded in it. It seems that the explosive was lowered a little deeper than it was intended, so that it took effect on the upper part of the granite as well as on the sand rock. The gas flow was somewhat increased and many fragments were broken from the granite. A quantity of granite chips was left lying on the ground where the sand pump was last emptied.

This discovery is one of the most interesting that has recently been recorded in the history of the petroliferous series and has an important bearing on the questions pertaining to the origin of the same.

Here is a considerable volume of gas lying but a few feet above the granite. It must have originated where we find it, for gas can not descend in the geologic scale. The law of gravitation forbids. Neither can it rise in the scale, for the shaly beds that form the roof of the gas rock are impervious. If they had not been the gas with its pressure of 340 pounds to the square inch, which is the same as 48,960 to the square foot, would certainly have risen to some higher level.

There is no indication of temperature above the normal in connection with its formation. A temperature of even 200° F., acting on this series of rocks, with the alkaline liquids with which they are here and there charged, would inevitably have worked important changes in the rocks themselves.

Silica is dissolved under such conditions and must have been reprecipitated in the rock series. Such quartzitic sheets would

be the terror of the driller and could not in any wise escape his notice, but he finds no such hardened material and moreover brings up in the sand pump good sized fragments of all the formations that he traverses and these in every case are entirely normal. The thin sheet of Cambrian limestone that lies just below the gas rock and just above the granite is compact and hard to drill but there is no trace about it of metamorphism by heat.

Precisely the same line of facts comes to view in the deep wells of western Pennsylvania and West Virginia. A well was drilled a few years ago at Titusville to a depth of 3553 feet. It is known as the Jonathan Watson deep well. The lowest stratum that the driller reached was the well known and widespread red Catskill. This stratum is everywhere inherently red, throughout this part of the country, because of the peroxid of iron that it contains. The fact seems to have deceived at least one driller who is quoted by Prof. S. F. Peckham [*Proc. Am. phil. soc.* 1898] as saying: "The soapstone became harder as they went down and was red in color; in fact had been burned like brick." This statement shows complete misunderstanding of the facts and in reality contains a serious misconstruction of them.

The Catskill beds are a normal part of every section in the region, but below them there are many hundreds of feet of gray, blue and black shales, retaining their fossils and all their normal characters. The redness of the Catskill is in no wise a sign of metamorphism by heat.

Prof. I. C. White, state geologist of West Virginia, who is our highest authority on all facts in this line, writes as follows: "I have personally inspected the slates in the Wheeling well, 4500 feet deep, and in the West Elizabeth well, 5500 deep, and in the latter, after the red Catskill is passed there are no red beds at all. The slates in this well for the last 3000 feet are dark gray or bluish gray, while in the Wheeling well, from which the red Catskill had disappeared to the westward, there were no red beds whatever below the Barren or Elk river series of the coal measures. The same conclusions and facts have been confirmed by hundreds of other deep borings within my knowledge."

The fact is, the deepest we have ever gone in the rocks of New York and Pennsylvania, the depth in some cases exceeding

one mile, there is no sign of metamorphism, but on the contrary, clear negative proof that the temperature of the series has never been as high as 200° F.

The gas of the Potsdam must have originated in or immediately below the stratum that contained it, but it could not have originated as gas, contemporaneously with the sandstone formation. The Potsdam must have had an impervious cover before the gas could have been developed. If the material had been in the form of oil, the storage could well enough be accounted for. The transformation of oil into gas is a process that we know to be going on in nature and we can be sure that time enough has elapsed in this instance to provide for its completion. That the gas carries so much carbon loosely combined and ready to be deposited as free carbon or lampblack, matches well with this view of its origin.

Is there any possible source of petroleum revealed in this section? The thin streak of Cambrian limestone, with its fragments of the shells of Lingulella and Obolella and its hints of trilobitic crusts shows the presence of life in the seas in which it grew. Living matter, as we have seen, can be easily converted, at least some forms of it, into the petroliferous series by artificial processes. What man finds easy, nature, in her great laboratory is likely to find still easier. It is not necessary to hold that the limestone in its present state has yielded gas by destructive distillation of its substance. Though darkened by organic matter, there is but little in it that even under the process named would be converted into gas, oil or tar. We may be doubly sure that no limestone like the Cambrian which we find here was the source of the gas or of the oil which preceded it. In the first place, there is not organic matter enough, and in the second, there has been no abnormal temperature.

If, in the early stages of its formation, the organic matter, the existence of which is attested by the fragments already referred to, had been converted into oil, either by a peculiar form of decomposition according to Hunt, or by a process of distillation in which "time takes the place of temperature," according to Peckham and others, the presence of petroleum or gas would be satisfactorily accounted for. But it is to be borne in mind that neither of the processes named has been proved to be

in actual operation in the world today. Both are assumptions, pure and simple, supported, however, by more or less facts that require some explanation.

The presence of granite, an igneous rock, just below the gas rock, has no significance whatever as showing the probability of any unusual source of heat. The temperature of the igneous rock must have fallen to the normal temperature of the crust before the sandstone was deposited on it, for the sandstone is a marine formation and its 50 feet of thickness require a considerable term of years for its accumulation on the seashore. There is nothing whatever to indicate that a rock of igneous origin, after it has taken its place in the regular series of surface rocks, is any warmer than an aqueous rock. In fact, we know that there is no difference whatever in this respect.

The gas from the Potsdam sandstone warrants two conclusions that we can not afford to miss, viz, first, the formation of the petroliferous series dates back to Cambrian time; second, it is entirely disconnected with any unusual or abnormal source of heat that could leave a record in the rocks.

A second well was drilled in Parish because of the strong persuasion of the driller that oil must be near. The driller offered to make a new test if the people would raise $600. The amount was forthcoming and a second location was made on the Wilcox farm, six miles e. n. e. of well no. 1, near the line of Antwerp township. This well was carried to 2080 feet. The gas was even feebler than in no. 1. Salt water is now flowing from the well, probably derived from some horizon above the plug. The citizens interested in no. 2 formed a sort of association and leased a large amount of land. This association still holds about 3000 acres. The drilling in Parish cost the people about $1200.

g *Central Square.* This village is in the town of Hastings. It is situated to the south and west of Parish. A deep well was sunk here at the time when the fever of drilling was spreading through the county. Frequent references have been made to it by drillers who were cognizant with all the facts pertaining to it, but Mr J. T. Kilham, who had charge of the work, gives the following record:

Drive pipe	18 ft
Medina sandstone (and Oswego)	862

Bastard rock (Pulaski shale)	549 ft
Black slate (Utica)	180
Trenton limestone, struck at	1609
Potsdam sandstone, struck at	2259
Granite, struck at	2415

The thickness of the Trenton limestone is given in the record as 747 feet. There is a lack of correspondence in the several records extant, but there is probably no error in the depth given for the granite, 2415 feet. The identification of the top of the Trenton limestone may have wavered. It is taken here as 1609 feet.

What was found in the well in the way of geologic interest has already been noticed. The Potsdam sandstone made a great impression on the drillers who were acquainted with the Pennsylvania field. It was a genuine surprise to them to find such a clear and sharp sandstone here, but it would not have been had they been conversant with the scale of New York. They honored the new-found sandstone with many indications of their interest. It was called by them "Virginia sand", "McDonald sand", etc.

Potsdam sandstone in this occurrence and in the Parish well and at Greig, Lewis co. has caused considerable trouble and expense in the questions it has raised to the people of this region.

h *Oswego.* Drilling has also been done for the city of Oswego, in its immediate neighborhood, but nothing was found to give encouragement to the prospectors. A well drilled in the valley reports:

Sandstone (Medina and Oswego)	600 ft
Shales (Pulaski and Utica)	597
Trenton limestone, at	1197

This well was entirely unproductive.

Section 2

Jefferson county

A few wells have been drilled in Jefferson county in the search for gas that is here being placed on record, and it seems proper to make a brief note of the fact, though no economic gains can be traced to the explorations here.

a *Adams.* One of the most thorough of these attempts was made at Adams, principally under the control and at the expense

of one man, Mr Rufus P. White. Mr White has expended between $7000 and $8000 and kindly gives to the survey the result of his experience.

It seems that natural gas has long been known in this vicinity. Many years ago a physician of the town, Dr Rosey, found gas escaping from the crevices of a rock bottomed stream. He managed to collect enough gas here to boil water. Later, Mr White discovered a gas spring in the Utica slate and by a little pains collected enough to accomplish the same result, i. e. to boil water. He attracted attention to the discovery by boiling eggs in this way at a picnic party. He came to learn of several springs of this character from most of which sulfureted water, as well as gas, escaped. Then came along the experience of Findlay, O., and of Sandy Creek, nearer home, and he was at last encouraged to apply the drill to the rocks that were themselves holding out so much promise. He brought about the organization of a company under the state laws for this purpose, the nominal capital of which was $10,000. The company obtained a franchise from the village corporation for the purpose of supplying the people with gas for fuel. The stockholders were not all equally enterprising and it came about that Mr White bought out the individual stockholders, one by one, paying to each the amount of his investment, till at last he became sole owner of the franchise. He then proceeded to carry forward the enterprise and went to Bradford, Pa., to purchase drilling tools. While there, an oil operator inquired of him where he was to use the drilling tools. On being told that they were to be taken to Jefferson county, N. Y., the operator took him aside into his private office and informed him that there was only one line in the world on which gas could be found. Bradford was on this line and its direction was northeast. If Adams, Jefferson co., lies northeast of Bradford, there is a possibility of gas discovery there; otherwise not. He then took a map and laid down a rule on it, marking a northeast course from Bradford. To the delight of both, Adams was found directly on the line. Mr White returned, inspired with great confidence. He brought back with him drilling tools for which he had paid $3000, and also four drillers, who were to be paid $4 a day. He entered on the drilling of the first well in April 1891. The drillers found six feet

of soil, drift, etc., and then entered the Trenton limestone directly. At 400 feet gas enough to run the boiler was struck and there were frequent accessions as the drill descended. At 600 feet, a stratum of soft rock called shale by the driller was struck. The well was tubed with one and one fourth inch pipe and packed at 314 feet. The casing was set, as Mr White recalls it, at 450 feet. The gas showed a rock pressure of 120 pounds. The driller struck granite at 915 feet and drilled a day or two in this formation at the rate of 30 to 36 inches a day. The total depth of the well is 921 feet. Mr White piped the gas to his house and also supplied a few of his neighbors. The use was enjoyed for six months or a year, but the supply disappeared suddenly, like a lamp blown out. The gas was undoubtedly drowned out.

It seemed that there was nothing in the experience to discourage Mr White. He took a new location, one mile farther south, took down the derrick used in no. 1, drew the nails and put it up again. He found here 33½ feet of drift, cased the well at 204 feet, struck gas at 350 feet and carried it to the boiler. Part of the drilling was done in this way, but the gas did not hold out to the end of the work. This well was packed at 267 feet and was tubed with two inch pipe. It was finished in the granite at 950 feet. A vein of salt water was struck at 400 feet, but was soon exhausted. Well no. 3 was located one half mile due north of no. 2. Drilling was begun in August 1891, but only an insignificant amount of gas was found here, much like that in the first well. This well reached the granite at 960 feet and at this point a strong flow of brine, very strong with salt and also very bitter, was released. It could not be controlled by bailing. It filled the casing and overflowed from the well mouth. Crevices are reported as found at times in the limestone so that the tools would drop a few inches. This well was packed at 360 feet, tubed with one and one half inch pipe, but nothing came of it. The different beds of rock changed from harder to softer, but if there are any sandstone beds between the Trenton limestone and the granite, they were not recognized or reported. Mr White has a large part of the original outfit left on his hands.

Small escapes of gas from the rocks are common in this region. Gas is also often struck in water wells, but no large stock has

ever been reached. A test of the field was necessary to satisfy the minds of the people, but farther tests are not required.

b *Watertown.* A company was formed in Watertown to test the territory with reference to gas and several wells were drilled in this interest on the south side of the town, but unfortunately authoritative and exact records of the work are not now obtainable. One of the wells drilled near Remington's paper mill is said to be 400 feet deep. A more circumstantial, but perhaps not more reliable, account gives 573 feet for its total depth. This report is to the effect that granite was reached at 140 feet and that the drill was kept at work in it till 433 feet were added to the depth of the well. It is certain that granite was found in some of the wells.

The valley of the Black river runs through Watertown and gives one of the finest natural sections of the Trenton limestone to be found in the state. It is scarcely inferior to the famous and typical section found at Trenton Falls. The several divisions of the Trenton are all recognizable in the gorge and some of the finest fossils of the state are credited to this locality. As to the interval between the Trenton and the granite, no data have been obtained. It is probable, however, that the Potsdam sandstone holds its place in this series.

Neither gas, oil nor water was found in the series penetrated by the drill, but in portions of the county the water obtained from shallow wells in the limestone is notably saline, and the saline water is in many cases also sulfurous.

At Rodman a well was drilled at about the same time as the Watertown wells, in which the granite is said to have been reached at 900 feet.

There is a possibility of small accumulations of gas in the southeastern section of the county, where the Lorraine shale covers the entire Trenton series. Conditions similar to those that are found in Sandy Creek, for example, occur here.

Section 3

Onondaga county

a *Baldwinsville.* By far the largest production of gas from the Trenton limestone thus far found in the state has been developed in Onondaga county. The village of Baldwinsville, which is the

center of this production, has a good deal of enterprise and business activity and has availed itself of the fine water power supplied by the clear and steady flow of the Seneca river, the outlet of the Finger lakes.

It could not be otherwise than that the experience of the villages near by, specially of Fulton and Pulaski, should inspire Baldwinsville to set the drill at work to ascertain its possibilities in respect to the new fuel. Fulton is but 12 miles distant.

A company was organized under the name of the Baldwinsville light and heat co. and drilling was begun in the late fall of 1896. Of this company J. T. Wilkins is secretary and treasurer and in fact has had the principal direction and control throughout its history thus far.

The first well of this company was located a little northeast of the village center on the Monroe farm. It found the Trenton limestone at 2250 feet and was drilled into this formation 120 feet, making its total depth 2370 feet. A good vein of gas was struck at this depth, the rock pressure of which was 1200 pounds. The driller was not prepared to control the well when gas was struck and it was left to blow wide open for 12 days, during which time the gas escaped to the amount of at least 1,000,000 feet a day. On the 13th day the well was tubed with three inch pipe and shut in and its utilization was immediately begun. Gas was furnished to consumers through meters from the first.

The section of the strata shown by the well is normal in every particular. Below the drift the Medina sandstone and shale are struck. The upper part of the sandstone is white, the lower red. Below the Medina the Oswego sandstone, bluish gray in color, comes in, and, in due order, the Pulaski shale. From the last named formation the Utica shale is distinctly separable, the boundary being perfectly defined. The boundary of the Trenton limestone below the Utica is also, in most cases, distinctly recognizable. A later well has been drilled into it 500 or 600 feet, but thus far no drilling has been carried to the underlying granite, which will be found at a depth of about 3000 feet.

In the Monroe well gas was found all the way down, in the Medina and Oswego sandstones and in the Utica shale, but the great volume came from the Trenton limestone. Warned by the unfortunate experience of Fulton, the Baldwinsville company did

not take on all the consumers of gas that it could have secured, but from the first determined to husband its resources and not to press its gas supply to the limit. For the first four months of the service the Monroe well was drawn on for 2,000,000 feet a month, or 66,666 feet a day, and this moderate use was marked by a notable decline in the pressure of the well. In March 1897, the pressure was 800 pounds. It declined rapidly thereafter and brought alarm to those cognizant with the facts, but by this time the second well had been carried well down into the Utica shale and was furnishing a considerable volume of gas. This supply was at once turned into the city line and presently the Monroe well was cleaned out and drilled a few feet deeper. 50 feet of shale, dropping from higher levels, had accumulated at the bottom of the well. This was removed and the driller set to work for a few feet on rock never reached before. According to some reports it was deepened 50 feet, which would make its total depth somewhat more than 2400 feet. Its volume was not only restored but increased and its pressure rose to a much higher figure than ever before, viz, to 1540 pounds. After allowing the well to blow for 24 hours, with interruptions, 1450 pounds was registered. The gas in July 1897, when observation was taken for the survey, showed a pressure of 1350 pounds. When returned to the line a decline of 45 to 60 pounds to the month was again experienced, while the gas consumed did not exceed 1,000,000 feet for the same length of time.

Well no. 2 was drilled in the river valley on the Wells farm and is known as the Wells well. The drill began work on it early in 1897. A good volume of gas was found in the Medina, reported at 400,000 feet a day, but at 1838 feet, in the Utica shale, the production became so large that it was impracticable to keep the tools at work. The well was tubed with three inch pipe at this depth and an open pressure of 2.75 inches of mercury was shown. This stands for a daily output of 2,126,270 cubic feet. The rock pressure at this time was 825 pounds, which was reached in 17 minutes after the gate was shut. As stated in the preceding paragraph the entire village plant (160 meters) was put on this well for a period of three months, and in this time the pressure was not reduced below 500 pounds. The tubing was set at 600 feet. This well has since been drilled into the

Trenton limestone and the experience has been very troublesome and costly because of "blowers" of gas that were once and again encountered in the descent of the drill.

Well no. 3, known as the Dow well, is located one half mile west of no. 2. At the time of my examination it had not been drilled to the Trenton. It found a strong gas vein in the Medina sandstone at 925 feet, which was not tubed and which was allowed to burn from the casing for a number of weeks. It furnished several tens of thousands of feet a day.

The records of two of the wells will here be given in somewhat more detail. The facts were furnished by John T. Kilham, an experienced operator from Pennsylvania, who entered this field in 1894 and has kept close and intelligent watch of every feature in the development thus far. The survey is under great obligation to Mr Kilham.

	Monroe (no. 1)	Wells (no. 2)
Drive pipe	38 ft	43 ft
Cased	348	250
White Medina	542	....
Red Medina	620	585
Oswego sandstone	1200	1223
Top of Trenton	2240	....
Packed	1350	618
Rock pressure	1375 lb.	825 lb.
Gas for boiler	1714 ft	639 ft

The management of the company has been conservative and wise from the first. It has sold gas by meter only and has refused to put on consumers beyond its ability to furnish an adequate supply. In consequence its service has been thoroughly satisfactory to its patrons, and the business promises fair financial returns to the stockholders.

From November 1896 to August 1897 the company supplied about 14,000,000 cubic feet of gas, all of it being furnished by wells no. 1 and 2 and mainly by the former.

The next step in the development of the field was taken by the firm of Pierce, Butler & Pierce, an enterprising and successful business house of Syracuse. This company is interested in a steam heating plant in the city and also obtained from the

city government a franchise for the use of the streets for piping natural gas.

It began operations in September 1896, under the name of the Onondaga gas co. Its first work was purchasing the leases of a considerable territory which had been taken up by Mr J. T. Kilham. Mr Kilham conveyed to the firm drilling rights on 5000 acres of land lying mainly to the south and southwest of Baldwinsville. A contract was at once entered into with the drilling firm of Stearns & Leopold to sink two wells. Drilling was begun at once. Well no. 1 was located on the Names farm, one half mile south of the Baldwinsville railroad station in the valley of the Seneca and on the north side of the river. There was nothing irregular or exceptional in the record of the well. The drift was shallow (20 feet) at the point where the well was located. The Trenton was reached at a depth of 2270 feet and at 2368 feet the first gas was struck. Drilling was continued to 2547 feet, the well being finished in November. It was tubed with three inch pipe and was packed at 1400 feet but was afterwards repacked at 630 feet. A little salt water was struck in the Oswego sandstone at 1210 feet. The rock pressure when the well was first shut in, was 1460 pounds, and the open pressure was 1.5 inches of mercury, indicating a flow of about 1,500,000 cubic feet a day. Later the well filled with water to a considerable depth. It had not been put into use when the field was visited in the interests of the survey.

Other items in the record of this well are the following: cased, 318 feet; white Medina (with gas), 600 feet; Oswego sandstone, 1285 feet; Pulaski shale, 1765 feet; Utica shale, 1878 feet. The Salina shale, 138 feet thick and 45 feet of Niagara limestone came in near the beginning.

Well no. 2 of the Onondaga company was drilled on the Van Ness farm, three miles southeast of no. 1. This well reached the Trenton at 2280 feet and was subsequently drilled to a depth of 3035 feet, but the stratum proved entirely destitute of gas. The only useful purpose the well could be said to serve was in proving territory. It has discouraged drilling to the east of Baldwinsville.

The next well to be drilled in the field was undertaken by a new interest, namely, the Trenton rock oil & gas co. The princi-

pal interest in this company belongs to the Rose brothers. A well was located on the Waffle farm, about two miles directly west of the village. It found the Trenton limestone at 2248 feet and was drilled to a depth of 2860 feet. It was packed at 480 feet and showed a rock pressure of 450 pounds. Its volume was small, not exceeding 200,000 feet a day. This well was "shot" with 110 quarts of nitro-glycerin, but without bringing any improvement. No use had been made of its gas up to the autumn of 1897.

During the summer of 1897 the Onondaga gas co. put down four wells, two located on the Talmage farm, about two miles south of the village, and two on the Spaulding farm, about four miles south of the village. The reduced record of Talmage no. 1 is given herewith. Gas was first found in the White Medina at 776 feet. The Oswego sandstone was struck at 1200 feet. The well was finished at 2020 feet. A fair volume of gas was found in the Trenton limestone, the rock pressure of which was 545 pounds when first struck, and 560 pounds in August 1897, when measured for the survey. The open pressure in the three inch tubing indicated a total output of 1,000,000 feet a day. The well was packed at 625 feet.

Early in August 1897, the Spaulding well no. 2 was drilled to the Trenton limestone, which it reached at 2404 feet. At 100 feet in this stratum gas enough to fire the boiler was obtained. Of the fortunes of Talmage no. 2 and Spaulding no. 1, record has not been obtained, but if they had achieved any marked success the facts would not have escaped observation.

The Binning well, so called, located on the Hickok farm, was the first venture of a new company in the field, viz, the Phoenix natural gas co., composed in part of experienced operators who had already taken part in the development of Baldwinsville gas. This well is located one fourth of a mile east of no. 1. It was completed in July 1897.

The Binning well was the seventh successful well of the Baldwinsville field, and being much larger than any of its predecessors, it attracted great attention and made a marked impression on the public mind. It was widely noticed in the newspapers of the day, mostly by reporters who had never seen a gas well except in this particular region, and who, finding this well much

larger than the wells that surrounded it, passed hurriedly to the conclusion that it was the greatest gas well ever found in the world.

The phenomena of a large gas well when first opened and before it has been brought under control are certainly impressive and newspaper reporters may well be pardoned for exaggeration in describing them. Strong words and vivid description are needed to convey to others the impression by which those on the scene are overpowered.

In reality the Binning well does not take a high rank among gas wells, so far as volume is concerned. It is credited with 3,122,000 cubic feet a day from a three inch pipe. In other words it is a respectable, but not a great well. To warrant its being included in the latter class its volume would need to be multiplied at least threefold.

Its rock pressure when first measured was, however, clearly of the first order. The gage recorded 1135 pounds and in August, when measured for the survey it had risen to 1180 pounds. It never reached the amazing figure reported for well no. 1, viz, 1540 pounds, the highest figure yet published from any gas well of the country. It will be remembered that this well, when measured in August 1897, showed a pressure of 1360 pounds. After the drilling of the Binning well the pressure of the Monroe well began to decline slowly, while the gage showed an increase in the pressure of the former. To those conversant with the facts it looked as if the wells were in some way in underground communication, and as if equalization of pressure would ultimately result. The longer experience to the present date will settle all questions of this kind.

The next successful attempt to reach the Trenton limestone was made by the Empire Portland cement co., near its works at Warners, on the New York central railroad, about six miles due south of Baldwinsville. This well reached the Trenton at 2696 feet, but the tools got fast soon afterward and several months were spent in freeing them. The well was finally completed in September 1897, a depth of 3526 feet having been reached. A small volume of gas was obtained but not enough, in itself considered, to justify the amount expended in sinking the well. The abbreviated record of this well and a second well, located one

mile west of the first is as follows: Drive pipe (no. 1) 160 feet; Medina sandstone, 1050 to 1850 feet; Trenton limestone, 2700 feet; Potsdam sandstone, 3500 feet.

The most interesting fact remains to be stated. While in no. 2 a small amount of gas was furnished by the Medina and the Trenton formations, the only important vein was found in the Potsdam sandstone. Gas was struck at 3526 feet. The amount was sufficient to run the boilers of two 125 horse-power engines for six or eight weeks. At the end of this time the volume fell away till there was barely enough gas for one boiler. The initial yield must have exceeded 100,000 cubic feet a day. The original rock pressure is said to have been 800 pounds. The granite has not been reached in either well, but it does not lie far below the bottom of no. 2, viz, 3600 feet. A third well has been located one mile west of no. 2 and two miles west of no. 1.

In November of the same year another well of great force was struck on the Kendall farm in the same district with the Monroe and Binning wells. It was drilled by the Onondaga gas co., which was also known as the Syracuse steam heating and power co. The rock pressure of this well was reported at about 1100 pounds. The Trenton limestone was reached at 2250 feet. At 2350 feet, or about 100 feet below the surface of the stratum, a gas vein of unusual force was reached. It drove the drilling tools and cable out of the well, throwing the drill high above the derrick. The cable alone weighed over 4000 pounds. It is certainly remarkable that more than 2000 feet of it should be lifted bodily and made to clear the hole, without binding anywhere. The well was "bridged" by fragments falling from above after the tools were blown out.

A well known as the Toll well was drilled still later in the same neighborhood and its character was in keeping with the wells that preceded it. These four wells, the Monroe, Binning, Kendall and Toll wells, mark the center and highest development of what may be called the Baldwinsville gas field.

The Onondaga gas co. laid a pipe line in 1897 from the Baldwinsville field to its works in Syracuse. Part of the line is six inches in diameter. One of the wells, Talmage no. 1, was attached to the line, and was used for a time in the steam heating plant at Syracuse, but a notable fall in the rock pressure is said

to have followed the consumption of a few hundred thousand cubic feet of gas a day.

It is commonly reported that this company has recently sold its entire plant, leases, wells, pipe-lines and franchises to the Syracuse gas light co. but the fact or the terms of the sale have not been made public. The use to be made of the gas will soon be determined, but it is probable that some of it will be introduced into the city gas line, to be intermixed with the artificial product.

During the past year the number of wells in and around Baldwinsville has been more than doubled, but no new features have been added to the field. Those who have drilled the later wells have kept well within the boundaries already established as covering productive territory, so that no additions to the latter have been made.

The most notable fact of the past year is the deepening of the Monroe well by the addition of 240 feet to its depth and a consequent great addition to its volume and restoration of its rock pressure, which had been lowered more than 1000 pounds. The Baldwinsville wells were greatly reduced by the winter demand, and if the month of March had not been unusually mild a shortage of gas would have been experienced in the village supply. After deepening, the well showed a rock pressure of 1350 pounds, which was gained in 15 minutes. Its volume, as measured by the open flow, was 3,737,000 cubic feet a day. This is the largest volume yet reported from any well in this part of the state.

The specific gravity of the Trenton limestone gas from the Baldwinsville field, and, no doubt, representing the gas of all the fields, was determined for the survey by Mr W. W. Randolph of New York, who is expert in this line of investigation. He made use of the "effusion method," employing modern apparatus of the most approved construction. The results of a number of observations showed the figure .551 to represent the specific gravity of the gas, but even this figure was held subject to correction.

The composition of the gas was determined by the Syracuse gas co., the analysis being conducted by Dr Durand Woodman of New York. The gas company kindly allowed the survey the use of its results, which are given below:

Composition of Baldwinsville gas

Acetylene	.00
Hydrogen (by the palladium method)	trace
Marsh gas	98.40
Carbon monoxid	.95
Carbon dioxid	.00
Illuminants, diffused	.25
Oxygen	trace
Nitrogen, by difference	.40
	100.00

Specific gravity, by calculation, .558

Heat units a cubic foot, 1013.5

Odor faint, resembling crude Pennsylvania petroleum.

These figures may be taken with all confidence as representing the composition and specific gravity of the Trenton limestone gas of New York.

In 1886-87 Prof. C. C. Howard of Columbus, O., made a number of analyses of the gas from the new fields of Ohio and Indiana and reported 92% to 94% of marsh gas, but also reported about 3% of nitrogen, 2% of hydrogen, together with a small amount of carbon dioxid. Prof. Howard afterward found reason to suspect that these latter figures were the result of erroneous methods of analysis, but did not have opportunity to repeat his work and eliminate the doubtful points. He also calculated on the same basis the specific gravity of Findlay gas and made it .566. If the corrections suggested should be found necessary, they would, when made, bring the composition and gravity of the Ohio gas to agree closely with Dr Woodman's figures for the gas of New York from the same stratum.

The only important difference between the production of the two fields would be found in the sulfur contents of the Findlay gas. This element does not occur in the gas of New York from the Trenton horizon. In Ohio and Indiana the sulfureted hydrogen of the gas is very noticeable and offensive. According to Prof. Howard the sulfur of this compound amounts to 1.25 grains to the cubic foot of Findlay gas.

The presence of the sulfureted hydrogen is not an unmixed disadvantage to the gas. By its odor it gives prompt warning of leaks in the lines of supply, and does a good deal to protect the users against danger from this source.

It would seem as if its presence is to be ascribed to the sulfureted water which is found in contact with the gas in many parts of the field. The Kingsville gas field of Ontario furnishes gas from an entirely distinct horizon, but under conditions similar to those found in Findlay and its gas has the same composition in all respects, including the sulfur contents.

The danger in the handling of the gas of the western fields lies in this fact, i. e. that the plumbing in many towns is so poorly done that the air is constantly loaded with the odor of the leaking gas, so that even dangerous leaks may escape observation. Careful and thorough work in plumbing should be insisted on in every town and in fact in every house in which gas is introduced.

It must be added, however, that no serious accident from explosions in connection with the recent discovery of gas has thus far been recorded in this state.

Is Baldwinsville gas shale gas?

To refer Baldwinsville gas, with its wells of large volume and of extremely high rock pressure, to the somewhat inferior division of *shale gas* as contrasted with *reservoir gas*, seems at first sight invidious and unjust, but the insignificant gas-flows from the rocks of Jefferson county, already described, where the Trenton limestone occurs in outcrop, admit of no other reference. They agree in all particulars with the small wells derived from shale formations of typical occurrence. But the gas at Sandy Creek and Pulaski clearly belongs to the same division as the gas of Jefferson county, being found in unmistakably the same horizon and having the same general characters. These characters can be stated as follows: 1) No two wells draw their supplies from exactly the same horizon, but the gas is frequently distributed through one or two hundred feet of the strata, the total flow being made up of numerous small veins. It is true, however, that gas is looked for more confidently at one particular range than another. 2) No two wells have the same rock pressure. The records of the Pulaski field, for example, have shown from

the first the considerable range of 165 to 650 pounds. A difference of several hundred pounds can sometimes be noted between two closely contiguous wells. 3) Salt water is not found in any considerable quantity in any of the wells and is entirely absent from most records, even of wells that are drilled to the granite. 4) No portion of the series from which the gas is derived shows porosity. There is nothing in its composition to indicate this quality. The Trenton limestone of New York makes no approach to its dolomitic phase, so far as the examination has thus far gone. Samples of the formation were taken for chemical analysis from various localities and particularly from representative points as Trenton Falls for the sake of comparison with the drillings of deep wells and as a possible aid in identification of the various elements of the sections traversed by the drill. The results did not meet anticipations but they are given below. The analyses were executed by Prof. Edward Orton jr, of Columbus, O.

Analyses of limestones of Trenton age

No. 1 Birdseye limestone from 10 ft ledge two miles below Poland, in bank of Canada creek.

No. 2 Average of 12 ft "velvet blue" rock at foot of stairway, Trenton Falls.

No. 3 Average of 20 ft uppermost section of Trenton limestone at Prospect.

No. 4 Drillings from upper beds of Trenton from well no. 2, Rome, 680 ft below surface.

	1	2	3	4
Silicious residue	5.14	5.63	1.52	8.16
Alumina and iron oxid	1.59	1.40	1.39	1.87
Calcium carbonate	91.11	90.56	95.56	86.03
Magnesium carbonate	2.18	2.45	1.81	3.49
Total	100.02	100.04	100.28	99.55

Analyses of Utica shale

No. 1 Lenticular mass of limestone in shale, Waterman's hill, near Poland.

No. 2 Average of 36 ft lowermost beds of shale, Waterman's hill, near Poland.

No. 3 Drillings from well no. 2, Rome, 350 feet below the surface.

1

Silicious residue	16.00
Alumina and iron oxid	3.30
Calcium carbonate	74.17
Magnesium carbonate	5.26
Organic matter, by difference	1.27
Total	100.00

2

	Total ultimate analysis	Analysis of that portion insoluble in H_2SO_4 & Na_2O_3
Silica	34.94	21.62
Alumina	10.77	.67
Ferric oxid	2.07	
Lime carbonate	43.80	.14
Magnesium carbonate	4.22	.16
Potash	2.15	1.06
Soda	1.91	
Combined water	0.47	
Manganese	trace	
Total	100.33	23.65

3

	Total ultimate analysis	Analysis of that portion insoluble in H_2SO_4 & Na_2CO_3
Silica	51.89	30.36
Alumina	18.84	.98
Ferric oxid	3.27	
Lime carbonate	7.41	.20
Magnesium carbonate	2.87	.28
Potash	2.80	.89
Soda	2.53	
Loss on ignition, CO_2, H_2O	10.39 (by difference)	
Manganese	trace	
Total	100.00	32.71

The most productive portion of the Trenton, in the judgment of drillers who have done the most work in the new fields, is the highly fossiliferous beds. Mr C. W. Vroman, for example,

felt quite encouraged in his Stillwater well, already described, when chips were brought up showing the presence of abundant fossils. These chips agreed perfectly in appearance with fragments of the *Orthis testudinaria* beds from Trenton Falls and other well known horizons of the limestone.

On grounds like these it seems necessary to class the Baldwinsville gas fields with the Pulaski and Sandy Creek fields. The gas lies much deeper and there is a much larger production, but it is essentially of the same character. The difference between the two varieties has already been pointed out on the preceding page, but in respect both to volume and rock pressure the Baldwinsville wells are far in advance of all the rest that are referred to the same division. A few hundred thousand feet of gas a day and a few hundred pounds of rock pressure make the record of the largest shale gas wells hitherto observed and recorded.

In regard to this last element, viz, rock pressure, the facts of the Baldwinsville field oblige us to extend the explanation that has thus far been counted sufficient for shale gas wells far beyond the limits heretofore recognized. The pressure in shale gas fields has long been counted due to the expansive force of the gas as it is generated. No other force adequate to the production of the result has been discovered.

The case is entirely different in the matter of reservoir gas, i. e. of gas stored in porous rocks that are also occupied by other fluids. The facts derived from the new fields of Ohio and Indiana brought to light another cause at once true, real and efficient, that gave a rational and intelligible explanation of all the phenomena involved.

It was observed that when salt water was struck in the Trenton dolomite it rose throughout the field to a fairly uniform hight of 600 feet above tide. Its ascent was obviously referable to artesian pressure. No other explanation is worth a moment's consideration. But the artesian pressure that forces water to rise in the porous rocks, would exert an equal pressure on any other fluid, as oil or gas, inclosed in the same porous rock. It was farther found that by taking account of the specific gravity of the salt water, the pressure, which is apparently due to 600 feet of the water, could be measured in pounds. The weight of

the column was found to be equal to 286 pounds to the square inch, the specific gravity of the brine being about 1.1.

At Muncie, Ind., the gas rock was found to be at tide level. The gas ought, therefore, to show a pressure of 286 pounds, if this explanation is correct. The testimony of experienced oil operators who observed the facts at the time the first wells were drilled was to the effect that the rock pressure was between 280 and 300 pounds. It is to be noted that only when the first wells of a field are drilled can the facts as to the original rock pressure be accurately found. New adjustments of the contents of the porous rocks become necessary when the equilibrium is once interfered with, and a great many circumstances come in to affect the rock pressure when drilling in a field has once got fairly under way. In default of exact information, therefore, it is safe to say that in this case the correspondence between the observed facts and the theoretic calculation of what the rock pressure should be is sufficiently close.

In Marion, Ind., the gas rock was found at a depth of 78 feet below tide. To the 286 pounds of pressure due at tide level there must be added the weight of the 78 feet of salt water below the level named. The amount of the true pressure was 323 pounds. Visiting the field when the first well was completed I found that the gage read 323 pounds. This fact was recorded before any theory whatever had been formed in regard to the cause of the rock pressure of gas.

A well at St Henry, in Darke co., O., found the gas at 200 feet below tide. After being allowed to blow into the air for three months its pressure was found to be 375 pounds. The 800 feet of salt water found here would exert a pressure of 385 pounds. It seems altogether probable that at least 10 pounds of pressure were lost in the three months of unrestricted flow.

In well no. 1, Upper Sandusky, gas was struck at 470 feet below tide, which would necessitate a rock pressure measured by a column of salt water of 1075 feet in hight. This would make the theoretic rock pressure of the gas 513 pounds. The actual pressure as reported by Dr A. Bilhardt, a careful and conscientious observer, was 515 pounds. Finally, at Tiffin, in the Loomis and Nyman well, gas was found at a depth of 747 feet below tide. The salt water column on the gas must

then have been 1347 feet, which equals 641 pounds. The gage by which the pressure was tested was graduated only to 600 pounds, but the index traveled beyond this point and the figure at the time was reported as 650 pounds. These facts may be stated in tabular form.

LOCATION	Depth to gas	Depth below sea level	Theoretic pressure	Observed pressure
Muncie, Ind	900 ft	0 ft	286 lb.	280–300 lb.
Marion, Ind.....	870	78	323	323
St Henry, O.....	1156	200	385	375
Upper Sandusky, O...	1280	478	513	515
Tiffin, O.....	1500	747	641	650

These are the best examples found that bear on this point, but the mind must be peculiarly constituted that can consider these facts as accidents.

The Kingsville gas field of Ontario is another case in point. It finds its supply in a very pure and porous dolomite of Silurian (Upper Silurian) age, and the pressure of all the wells drilled, 30 or more in number, is approximately the same, viz, 400 pounds. Where the gas is withdrawn by a pipe line, the pressure falls equally in all contiguous wells, whether connected with the line or not. The hight to which the salt water rises has not been fully determined as yet, but the highest pressure noted, namely 415 pounds, would show a water column of 850 feet, if the specific gravity of the salt water found proves to be the same as that in the porous Trenton of Ohio. As the wells are drilled about 1025 feet to the gas vein and as the elevation of the surface is approximately 600 feet above tide, the salt water should be found to rise to within 175 feet of the surface. If this is hereafter found to be the case, it will complete the demonstration in the most conclusive manner. It is to be noted that observations will be valid only in wells that are cased below 500 feet, as a fresh water vein of great force is reached at about this depth.

There are two distinct forces, then, that take part in the rock pressure of natural gas, viz, its expansive power, and the weight of the salt water column that compresses it. The first cause may exceed the second, and in such cases it would completely mask the latter. Where no porous rocks are found and where a water column is therefore wanting, we are obliged to rely altogether on

the expansive power of the gas. There is a certain unexplained relation between the rock pressure and the depth at which the gas is found. To the understanding of this relation we may confidently expect to attain, as intelligent exploration goes forward.

The conclusions, then, in regard to the rock pressure of gas are as follows: First, there is a pressure arising from the expansive power of the gas itself, and this, so far as observation is concerned, reaches its highest mark in the Monroe well at Baldwinsville, namely, 1540 pounds to the square inch at a depth of 2370 feet. Second, when the stratum that holds the gas is porous and continuous, it must contain water, fresh or salt, in some portion of its extent. Whenever this water shows itself under artesian pressure it must of necessity exert on the oil or gas with which it is in contact the same force that causes the water itself to rise. The rock pressure of the gas can then be measured by the weight of the salt water column. Enough observations are on record to establish this deduction on a solid foundation. But it is possible that the expansive power of the gas may exceed the pressure which the water column would put on it. In this case this element will escape observation altogether. This explanation of rock pressure imperiously requires certain conditions, viz, a continuous porous stratum rising somewhere to day and thus acquiring artesian pressure.

In the development of the Baldwinsville field no theory found place in the location of the earliest wells. Convenience alone was consulted as to where they should be placed. The northeast line, which is based on sound geologic observation in Pennsylvania and western New York, but which is generally a delusion and superstition when applied to other territory, was introduced by the drillers after gas was discovered. An amusing instance occurred in connection with its application to the location of the Binning well.

It is important to the contractor who drills a well to find gas as soon as possible for the boiler that supplies the drilling power. The first gas to be found in any of these wells is in the white Medina sandstone. The Talmage well, no. 1, found gas enough for this service in the horizon named. The Wells well had also the same good fortune. The contractor who was to drill the

Binning well had the same object in view, and for his own guidance drew a line through the two wells named, extending it to the farm on which the new well was to be sunk. A location on the farm had already been selected, but when the contractor came on the ground he changed the location by about 400 feet, to bring it to the line above described and spoke rather vaguely of the importance of the exact location, but without giving his reason for the same. Now it turned out that the Binning well found no gas whatever in the Medina but obtained a much larger flow from the Trenton than any of the wells that preceded it. The interest of the contractor in a particular location and the exceptional volume of the well were put together by those partially conversant with the facts and the success of the well was credited to the exceptional prescience of the contractor, while in reality he had completely failed in the object for which the northeast line had been invoked.

Of course where the accumulation of gas depends largely on the structure of the strata, as has been urged in a preceding part of this report, lines will be found in such fields indicating the higher portions of the rock that contain the gas. Such lines might bear northeast and southwest, but there is no more reason why they should take this particular direction than any other.

The most important structural lines in the new oil fields of Ohio are north and south lines, or, in some instances, lines running a few points west of north. In the Rocky mountains the main lines of uplift are northwest and southeast, while several of the European axes are practically east and west lines.

Section 4

Oneida county

A considerable amount of drilling has been done in Oneida county within the last few years. Deep wells have been sunk at Utica, New York Mills, Rome, and in various other localities. At the two localities first named, the avowed object was not to search for gas or oil. Water was more distinctly in the minds of several of the projectors of these expensive explorations. The drilling has been carried on in several instances by manufacturing companies and in their work they have not seemed to count the cost very carefully. The drill has several times been

sunk for hundreds of feet into granite, where porous rocks are not known to exist and where no encouragement whatever is found in the results of experience. In but one of the towns named, Rome, has there been a definite search for gas and intelligent prosecution of the work.

a *Utica.* In 1896 the Globe woolen works drilled a well in the search for water to a depth of over 1800 feet. Mr P. H. Foley of Utica was the contractor and he has furnished the following record, his nomenclature being somewhat modified.

Drive pipe	48 ft
Utica shale	447
Trenton limestone	369
Potsdam sandstone	440
Granite	551
Total	1855

A gas vein was struck at 225 feet of force sufficient to throw the water from the casing and to make quite an imposing blaze. The pressure of the gas was estimated at more than 200 pounds to the square inch, but the vein was finally cased out of the well and drilling went forward. The contractor divided the great limestone series into two divisions, the upper one being styled a "fossiliferous limestone," but the geologist can not recognize the grounds of this division. Both are unmistakably Trenton. The distance from the top of the Trenton to the granite is normal for this region. Through several counties the measure is about 800 feet.

The experience of this well shows that Utica has enough evidence of gas to justify farther exploration, if her citizens come to attach as great value to this volatile fuel as many of their neighbors do.

The Standard harvester co. also sunk a deep well in 1897, the record of which is as follows:

Drive pipe	65 ft
Utica slate	497
Trenton limestone	368
Potsdam sandstone	4
Total depth	934

A considerable vein of gas was struck in this well at about the same horizon as the gas in the preceding well.

Several other wells have been drilled within the city limits, in all of which weak veins of gas have been found in the Utica shale or in the underlying limestone.

b *New York Mills.* In this manufacturing village, three miles west of Utica, a deep well was drilled a year or two since by Mr Campbell, in an unsuccessful search for water. The record is in some respects a surprising one. Granite was struck at 1000 feet and the drill worked its way slowly down into these stubborn foundations for 1100 feet. This is the deepest boring in granite which the records of this country afford. So far as our knowledge goes, there was nothing whatever to justify such an expenditure.

The records of the Campbell well do not seem to have been so kept as to furnish any facts of scientific interest and there is no economic interest apparent in any of the history.

c *Rome.* A resolute and intelligent search for natural gas was begun in Rome in 1896–97, and has advanced till a number of important facts have been brought to light. The distinct search for gas was preceded by the drilling of a deep well, primarily for water. The successful experience of Utica in the way of obtaining artesian water inspired a like attempt in Rome.

In 1896 a number of the more enterprising and public spirited men of the town effected a loose organization among themselves known as the Factory building co. The object of the association is expressed in the name it took. It set before itself the distinct purpose of introducing and supporting manufacturing enterprises. In this interest it bought 18 to 20 acres of land on the east side of the town and established works for the manufacture of tea-kettles. To farther aid this enterprise, the company proceeded to drill a well on the ground of the new works for the particular purpose above named. A contract was entered into with Rusk & Co. of Ithaca to supply an artesian well. The contract covered a descent of only 300 feet.

The well head is 425 feet above tide. Work was begun in October 1896. The driller found 115 feet of drift; this fact revealing old conditions in the valley of the Mohawk very different from those prevailing there now. The composition of the drift

was as follows: soil, 3 feet; sand, 16 feet; blue clay, 20 feet; black sand, 25 feet; blue clay, 20 feet; conglomerate gravel, 31 feet. The gravel was full of water. At 116 feet the black Utica shale was struck and at 216 feet a small vein of gas was found.

The discovery of gas, even in this small supply, changed the whole situation in the minds of the company. One of the most active and influential members of the organization had seen a little something of natural gas in the regions to the northward already described and he now proposed that the driller should go forward and develop the possibilities of this location in this regard. The Trenton limestone was reached at 630 feet. A second vein of gas, stronger than the first, was struck at 690 feet, and another considerable addition was made at 832 feet. The last vein was in fact decidedly the strongest of the three.

Drilling was continued to 1005 feet but without any other notable accessions of gas.

The well was cased at a little over 200 feet, but the work was imperfectly done, some leakage continuing. A light vein of salt water came with the last supply of gas and made more or less trouble in the pipe.

The use of the gas was however at once entered on. The rock pressure was found to be between 80 and 100 pounds. There was not enough gas to supply the boiler of the works, but all that there was was turned to good account at once in this way. A meter showed that the amount used ranged from 142,570 cubic feet a week in March to 51,490 cubic feet a week in June. At this time the well was retubed with some advantage to its production.

This discovery led to a more definite and thorough search for gas in Rome. A second well was at once projected and work was begun on it early in the succeeding year. This well was located on the grounds of the Brass and copper manufacturing co., which is the most successful and important industry of the town. The works are centrally situated in the town.

The record of well no. 2 as made out by Mr J. G. Bissell is in brief as follows:

Drive pipe	126 ft
Utica slate	509

Trenton limestone, struck at 635 ft..... 500 ft
Calciferous sandstone, struck at..... 1135
Granite, struck at..... 1560

Two veins of salt water, one at 1135 and a stronger one at 1175 feet, were discovered in the descent. The Potsdam sandstone began, according to the determination of the drillers at 1290 feet.

A full set of samples of the drillings was kept by Dr W. S. Kingsley, one of the principal stockholders of the Brass and copper co. as well as of the Factory building co. Dr Kingsley kindly allowed me the full use of these samples and the careful examination of them gives warrant for the following section.

Drift, 125 feet	Soil and clay	16 ft
	Dark, fine grained clay	34
	Dark, gravelly clay	16
	Dark and coarse gravel	29
	Finer gravel	12
	Fragments of Utica shale	10
	Coarse gravel	8
Utica shale, 500 feet	Upper beds at	126
	Very dark shale	350–450
	Hard shale	550–630
	Calcareous shale at	658
	White flakes of lime, approaching Trenton limestone	
Trenton limestone, 435 feet	Upper beds at	660
	Pepper and salt rock (gas found here) at	680
	Light blue limestone at	715
	Light gray limestone	735–765
	Dark blue limestone, hard, at	855
	Limestone, alternately gray and blue	875–925
	Limestone, alternately gray and black	925–1000
	Limestone, black and hard	1020–1025
	Limestone, softer	1025–1080
	Limestone, shaly	1080–1085

Calciferous and Potsdam	Sandstone, bluish, at	1095 ft
	Gray sandstone at	1106
	Salt water, weak vein, at.....	1125
	Dark sandstone at	1135
	Salt water, stronger vein, at.....	1175
	Gray sandstone at	1295
Red granite, probably struck at		1560
Micaceous band, 16 feet thick, at.....		1582
Red granite.....		1598

A flow of gas of great energy was found on April 3 at 830 feet. It held up at first in open flow a water column of six inches in the casing. This would indicate a production of about 3,500,000 cubic feet for 24 hours. In three days time, however, the open pressure was so reduced that it held up but one inch of water. Even this figure stands for a million feet a day. After the well was completed and the gas from this and all other horizons was gathered into the three inch tubing, the volume was found to be about 500,000 feet a day.

The discovery of this " blower " naturally aroused great excitement in town. For a few hours there was no stock of the drilling company in the market. Golden visions of a " boom " at hand led every one to revise at least mentally the selling price of his real estate, but as the gas vein exhausted its energy the town dropped back to its ordinary business level.

The real features of the situation soon came to be recognized. A volume of 500,000 feet of gas a day under 100 pounds rock pressure would not make a basis for a manufacturing plant, though even for such purposes the amount of gas is too large to be despised, but when applied to the lighting of a city or to a supply of domestic fuel for residents who would be glad to pay for such a luxury, this volume would make a very respectable figure. At 25 cents a thousand it would yield $125 a day. This view of the case came to be accepted by several of the leading business men of the town and several new wells were forthwith ordered.

The first of them was one drilled by J. S. Hazelton, at his residence on N. Washington st. It was finished in October 1897, at a depth of 890 feet. A fine vein of gas was struck at this depth. The well was tubed with two inch pipe. The rock pressure ran up to 100 pounds in 40 seconds, 200 pounds in 3 minutes,

250 pounds in 5 minutes. The open pressure was not recorded but the initial flow of the well was estimated at 1,000,000 feet a day. The wastage of gas was reduced to a minimum by having everything in readiness when the main vein of gas was reached.

Mr Hazelton designed to apply the gas exclusively for household use, where every foot of it stands for comfort, as well as for money value and the waste of it was recognized exactly like the reckless waste of any other form of wealth. The well supplied his house with fuel and light through the winter. Salt water came in later. The tubing was drawn and the well deepened to about 1000 feet. It shows 40 to 50 pounds pressure at the present time.

The second of these wells was drilled by Dr J. W. Kingsley at his residence on E. Liberty st. It was also about 1000 feet in depth. Its gas supply was small and no satisfactory service has been rendered by it.

A well drilled by C. M. Humphrey in the northern part of the corporation for his greenhouses proved successful, but the amount of gas furnished by it is not equal to the demands of his extensive establishment. Natural gas is an ideal fuel for this line of business and the present supply will answer an admirable purpose for the fall and spring months. Its present pressure is 200 pounds.

A fourth well was drilled near the center by Mr George Oster. Its volume is not large but it suffices for light at least in several buildings and also furnishes fuel for the boiler of a 35 horse power engine.

The fifth of these wells was drilled on the premises of the R. M. Wilson factory. It was finished in February of the present year, 1898, at a depth of 1125 feet. At the time it was brought in it gave the best promise of the entire series, showing a rock pressure of 450 pounds to the square inch. It was applied at once to the boilers of the two 175 horse power engines of the factory and kept them running 10 hours a day for a number of weeks. This service, however, proved too severe for the capacity of the well, and, as the gas was specially valuable in brazing and soldering in the factory it was withdrawn from the boilers altogether. The pressure at the present time is 350 pounds to the inch.

Characteristics of the Rome gas field

The last of the Trenton limestone gas fields of New York as at present developed has now been described. No metes or bounds can at present be assigned to it. A half dozen wells have been completed within an area of not more than one square mile and all have secured more or less gas. Most of the gas was derived from a depth between 800 and 900 feet; or in other words, from 200 to 300 feet below the uppermost beds of the Trenton limestone. By comparison with the preceding records it will be seen that the largest production of all the districts comes from this central portion of the Trenton series.

The highest rock pressure reported thus far is 450 pounds. The largest measured volume is 500,000 feet a day, but the estimates of the "blowers" when struck credit them with at least 1,000,000 feet a day. No advantage has thus far been found in drilling wells more than 1000 feet in depth. As a rule the fresh water can be excluded entirely from the well by a casing of not more than 200 feet. But little salt water has thus far been encountered. Drive pipe to the extent of nearly 150 feet is required in the old valley that passes through the town, but in the immediate neighborhood the Utica shale has surface outcrops and in a good deal of the surrounding territory the deposits of drift are very shallow. By competition the price of drilling wells will doubtless be brought down to 75 cents a foot or even to lower rates. No reason is apparent why the one square mile within which the drilling has been confined holds any more buried fuel than any other square mile of the vicinity. Wells, some of them better and some less productive than those described, can undoubtedly be found throughout the region. Occasional "blowers" and occasional failures will be met.

Section 5

Proper use of natural gas

Natural gas is the best fuel known to man. No advance beyond it is possible, but to secure the best results some scientific knowledge is required in regulating its combustion. Since it is the perfect fuel it admits of application to almost every purpose to which fuel can be turned. The principal exception is in the manufacture of iron from its ores and in other similar metallurgical processes. In the working of iron in rolling mills, forges, and foundries, and in the production of steam for all its multi-

farious applications, in the direct use of heat, in the manufacture of glass and cement, in the burning of pottery, tile, and brick, it is, as before said, the perfect fuel. It effects important economies and greatly improves the quality of production at the same time. But superlatives in describing its advantages and value ought to be reserved for its use as a household fuel. It is here that it does the greatest good to the greatest number. It lightens and simplifies the labors of housekeeping to a surprising extent.

The truth is that natural gas ought to be exclusively confined to domestic use. It is too good for any other line of service, too fine a product for the coarse applications already named. It is a profanation of the good gifts of nature to use gas in burning bricks and tile, in calcining limestone, in generating steam, in the manufacture of glass or cement. There is not enough of it anywhere for manufacturing purposes. The most prolific districts for its supply thus far known in the world, have been two areas, each of which can be described with a radius of 30 or 40 miles; one, around Pittsburg, Pa., as a center, and the other around Fairmont, Ind. Though less than 20 years have passed since the first field was opened, and less than 10 years since the second entered on its course, we are already obliged to use the past tense in giving the history of both fields. Gas was applied in Pittsburg to manufacturing uses in every way that ingenuity could devise, but the life of the field could not be maintained under the draft imposed for more than a single decade. In other great gas fields like Findlay, O., the application to manufactures has run even a shorter race.

The amount of gas required in manufacturing necessitates the speedy decline and failure of every gas field, even the greatest. There is not a process to which it is turned, unless it be steam production, in which hundreds of thousands of feet, if not millions, are demanded every day. For steam production, 50 feet an hour for each horse power is probably enough, under careful and skilful use of the gas. This would make the consumption of a 50 horse power engine working 10 hours a day, 25,000 feet.

For glass manufacture, a 10 pot window glass factory would be found to require about 600,000 cubic feet a day. A 10 pot flint glass factory will use about 400,000 cubic feet a day.

Iron working demands by far the most lavish and unwarrantable use of gas of all manufacturing industries. A rolling mill will range from 1,000,000 to 5,000,000 feet a day. How far will a million feet go in the support of household use? A house of 12 rooms, using gas in cooking range, laundry, furnace, and in six grates, uses on an average for the year, about 40,000 cubic feet a month, or 1333 feet a day. 1,000,000 feet would supply 750 such establishments, or what the smallest rolling mill would use in a day would serve such a home for more than two years. But, instead of using 1333 feet a day, the average residence will find all its necessities met by less than one half the amount named. 500 feet will make an ample daily supply for the majority of city or village homes. For such use the amount consumed in the smallest rolling mill in a day will serve 2000 ordinary residences for the same length of time, or would serve one such dwelling for 2000 days. A 10 pot window glass factory uses what would supply 1200 dwellings for an equal length of time.

The sacrifice of human comfort and well being to business greed finds a striking illustration here and can not be too emphatically condemned. The application of natural gas to manufacturing uses necessarily involves such a sacrifice.

The country as distinguished from the village or the city ought not to consider itself excluded from the benefits of natural gas. It seems altogether feasible for well-to-do farmers in districts where gas is easily reached to drill wells for home supply. A well not exceeding 1000 feet in depth can be drilled and equipped for $1000 or less. If it can furnish light and heat for the home for 10 or 12 years the investment will be a safe one even from a business point of view, to say nothing of the incidental advantages that gaseous fuel brings. So also several farmers whose lands are contiguous could unite in drilling a single well and share its production in common. Such a venture might be distinctly advantageous to each, from the point of view already named, viz, dollars and cents. Whoever has occupied for a year a dwelling adequately supplied with natural gas, will recognize so many and so great additions that it makes to the comfort of life that he will not insist on a very close balance of expenditures and credits in dealing with this subject.

When applied to manufactures it is doubtful whether natural gas works in the interests of the general good. It is true that the cost of manufacture is cheapened and the quality of the production is likely to be improved by its introduction. But the fortunate manufacturer who can avail himself of it at once begins to undersell his competitors who are working under the old conditions, because his fuel, which is often the most costly element in his business, costs him nothing. In this way the most prudent manufacturer carrying on his business in the old way may find himself forced to the wall. Competition for him is simply impossible till the storm is past. Meanwhile the manufacturer who uses natural gas finds his business greatly improved in volume for the time being, because of the discouragement and failure of his natural competitors.

Such a state of things is not good for any community. It is much worse when the towns that find gas within their reach invite in manufacturers by municipal grants and the like. Factories come to be established, far from all supplies of essential materials with the one exception of fuel. As soon as fuel fails, the factory is bound to disappear. In many such cases, the last state of the town is worse than the first.

One of the evil results of the use of natural gas in manufactures is the development of the speculative fever called a "boom" in the towns that find gas at hand. Real estate feels the effect soonest. Inflated values derange legitimate prices, and the reactions that are inevitable are always hurtful.

From the temptation to the shameful abuse of applying natural gas to manufacturing purposes the newly developed gas fields of central New York are delivered. In but one of these, i. e. the Baldwinsville field, is the amount of gas large enough to make any figure in such an application and a brief experience in attempting to supply 1,000,000 or more feet a day to individual consumers will satisfy the owners of the Baldwinsville wells that this policy must be short lived and ruinous.

The proper use of natural gas, i. e. household use, is the only one that can bring adequate return to the company undertaking to supply it. It is a source of satisfaction to find that the true use pays best.

The price of gas ought to be increased in every community that is now using it. There is no good reason why it should be sold at any less price than the fuel which it displaces, or, in other words, why the better article should be sold for less than the inferior; in computing the cost of the displaced fuel, account should always be taken of the various items involved, such as its storage and preparation, the cost of lighting fires and the expenses of removing ashes and cinders, none of which enter into the use of gaseous fuel. It may be urged that an increased price for gas would result in extravagant profit for the gas companies. It can not be denied that there is a possibility of such a result, but as a matter of fact there are very few cases in the country in which companies have got back their original investment or see any good chance of getting it back. They are generally obliged to content themselves with generous dividends while the gas is in full flow.

The question of the municipal ownership of natural gas plants has not as yet come up in New York. Theoretically there is almost everything to be said for such a scheme, but practically it is hedged around with great difficulties, most of which can be referred to the unworthy views that prevail in all our communities in regard to the public service. No examples can be brought from the many trials of the system in Ohio and Indiana within the last few years to encourage its introduction into other territory.

Section 6

Summary

The natural gas fields of central New York have now been passed in brief review. A summary of the facts will be here presented.

1 Supplies of gas are found to be derived from several geologic formations, as the Medina sandstone, the Oswego sandstone, the Utica shale, the Potsdam sandstone, but the main dependence is on the Trenton limestone. It is this formation which gives character and value to all the rest. The others would have no considerable significance without it.

2 The gas of the Trenton limestone has the characteristics of shale gas. The several fields now developed do not seem to be connected by structural lines or to be arranged in belts, after

the fashion of the great fields of Pennsylvania and Ohio. The gas apparently occurs throughout the entire formation, except where the physical condition of the limestone is such that storage is wanting. While there can not be said to be any definite horizons of the gas, there are two divisions of the Trenton formation that furnish the main supply. The first is found 50 to 100 feet below the surface of the limestone; the second 50 to 100 feet above its base. There is no dolomite in either of the horizons, but the drillings show the presence in abundance of characteristic Ordovician fossils. The limestone holds comparatively little water and what water is found is generally saline, but not sulfurous.

3 The rock pressure of the gas ranges from a score or two of pounds to 1540 pounds to the square inch. The last named figure is the highest gas pressure known to be reported from any field in the world. From some unexplained cause, the depth at which the gas is struck has a general relation to the rock pressure, but adjacent wells differ widely in the figures reached. The rule seems to be, the deeper the gas vein, the greater the pressure.

4 As to the volume of the gas wells, a large range is also found. The largest volume reported thus far is 3,000,000 feet a day, but the ordinary wells show only thousands or tens of thousands of cubic feet, or, in rare instances, hundreds of thousands. The Trenton limestone is not thus far a source of large wells nor has it proved itself a large producer of gas to the acre or square mile.

5 When wells are wisely used they show a good degree of vitality. This is also characteristic of shale gas.

6 An *exact* determination of the dip of the strata is not possible from the data available. In fixing the different horizons of the rocks we are obliged to depend largely on the discriminations of the well drillers, and there is no certainty that they will agree as to the boundaries of the several formations that they undertake to identify. Neither are their records of the same well in all cases entirely harmonious. There is special liability to confusion in the case of the Trenton limestone. The lowermost beds of the Utica shale are generally highly calcareous, and the highest beds of the Trenton limestone are sometimes

shaly, so that the dividing line between the two formations is in many cases an arbitrary one. A swing of several scores of feet is possible in the fixing of these horizons as they are recognized by different drillers.

The best element in the series, that as to the position of which there should be the least ambiguity, is the upper surface of the Archaean granite. By its hardness it is so sharply contrasted with all other formations that the driller always knows when he has reached it, but there is a chance for discordant measurements, and, as a matter of fact, many of the records are confused and uncertain as to the depth at which the granite lies. Selecting a few records that are at least as good as the rest, we obtain data which can be used in determining the problem of the dip.

In central Jefferson county there is no doubt that the granite lies about 900 feet below the surface.

At Adams, it is given as		915 ft	
At Pulaski,	Oswego county	1425	
At Parish	" "	2445	(?)
At Central Square	" "	2415	
At Stillwater, Orwell township		1697	

Several of these points are on an approximately north and south line and the facts of the dip presented by them are shown in the following tables. Distances are taken from maps and from railroad measurements.

The elevation of the surface necessarily comes into account. The altitude of the points named below are herewith given. The calculations were made on the true elevations, the differences of surface altitudes having been first eliminated.

Adams, r. r. station	599 ft	above tide
Pulaski, "	377	"
Parish, well head	474	"
Central Square, well head (399.9)	400	"
Mexico, r. r. station	375	"
Baldwinsville, "	390	"
Warner, r. r. station	427	"
Stillwater, "	900	"

	DISTANCE	DESCENT	RATE
Adams to Pulaski	22 miles	288 ft	13 ft to mile
Adams to Central Square	41.4 "	1699	41 "
Pulaski to Central Square	20.1 "	967	47 "

Taking the Trenton limestone as a base, we find it reported as follows:

Pulaski	550 ft	below the surface
Mexico	1027	"
Central Square	1609	"
Baldwinsville	2250	"
Warner	2600	"

Calculating on the basis of the facts above given, we obtain results consonant in a general way with those previously reported. They are shown in the accompanying table.

	DIRECTION	DISTANCE	DESCENT	RATE
Pulaski to Mexico	Southwest	$8\frac{1}{2}$ miles	479 ft	41 ft to mile
Pulaski to Central Square	South	22 "	1036 "	47 "
Pulaski to Baldwinsville	Southwest	30 "	1687 "	56 "
Baldwinsville to Warner	South	$5\frac{1}{2}$ "	313 "	57 "

The figures of the tables above given will allow still other calculations than those that have been made. The calculations establish the fact that the strongest descent is in a southwesterly direction and that the dip increases slowly to the southward.

It has been a genuine surprise to find at this late day any part of central New York in possession of a considerable stock of stored power. The form in which this stored power is found is the most uncertain and in some ways the hardest to control of all its forms. But it is after all delightfully adapted to the service of man and can not fail to be appreciated and valued when its true character comes to be understood.

For the first century of its occupation in a large way the state depended for fuel on the noble growth of forests with which its surface was originally covered. 50 years ago, its forests being no longer able to meet the ever-increasing demand, specially for power to use in locomotion and manufactures, it began to draw

on the coal fields nearest to its limits. The coal field that it found most accessible was beyond question the noblest body of fuel known in the crust of the earth, viz, the anthracite field of northeastern Pennsylvania. By the middle of the 20th century, that is, in 50 years from now, if the present rate of consumption and the present rate of increase of consumption are maintained, this great treasure house of stored power will have been practically exhausted. Whenever this consummation is recognized as imminent, a new appreciation of all the forms of stored power, as winds, rivers, and soils, will be sure to be developed, and then the knowledge that a tract of land contains within its boundaries all the fuel and artificial light that its owners will require for decades, generations or centuries, will certainly become a factor in the value of such property.

CHAPTER 4

Lake shore natural gas belt of Chautauqua county

The belt of country bordering Lake Erie in Chautauqua county is a beautiful and favored tract. Its southern boundary is the continuous escarpment that faces the lake, five to seven miles back from its shore and which rises to 800 feet above its level, within the distance named.

The surface of the belt is occupied with two lines of transported material, viz, 1) the glacial drift, with its usual variety of composition; and, 2) deposits from the lake when it held a considerably higher level than at present. Under the first division we find wide stretches of boulder clay, giving rise to strong but heavy soils; the latter are often blackened by organic matter due to the swampy conditions of an earlier state. Under the second we note specially the extensive beds of sand, gravel and loam which mark the beaches or lake ridges that were thrown down in the higher stages of the water. These last accumulations give rise to warm and mellow soils which are also generous and productive.

To the advantage of the soil must be added that of climate. The immediate neighborhood of Lake Erie insures late springs, thus averting to a considerable extent the danger from spring frosts; while the presence of the same body of water, warmed by the heat of summer, holds off autumn frosts, thus allowing time enough for the ripening of grapes.

These two elements, soil and climate, have led to the recent transformation of a considerable portion of this belt into vineyards, orchards and gardens of small fruits. Probably this fruit culture is more indebted to climate than to soil, for we find vineyards as successfully established on the heavy clay lands as on the gravelly loam. On the clay lands their fruit requires a somewhat longer time for ripening, but is counted of finer quality.

At best the surface deposits of this lake shore belt are thin. It is rare to go down more than 20 to 30 feet without reaching bedded rock. The largest streams of the district all occupy new valleys, as is attested by the narrow rock-walled and rock-bottomed gorges in which they flow. The altitude of the most characteristic portion of the belt is 650 to 750 feet above tide. The differ-

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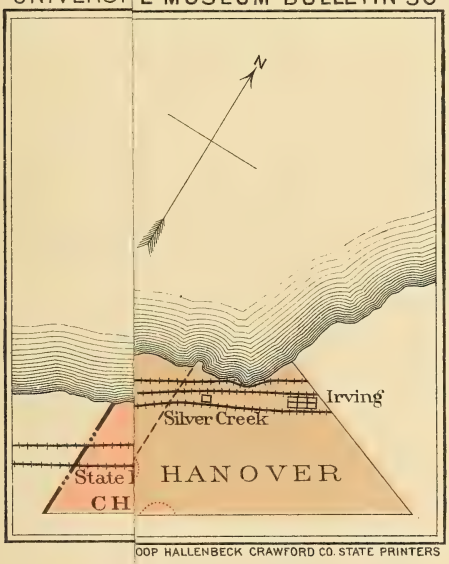

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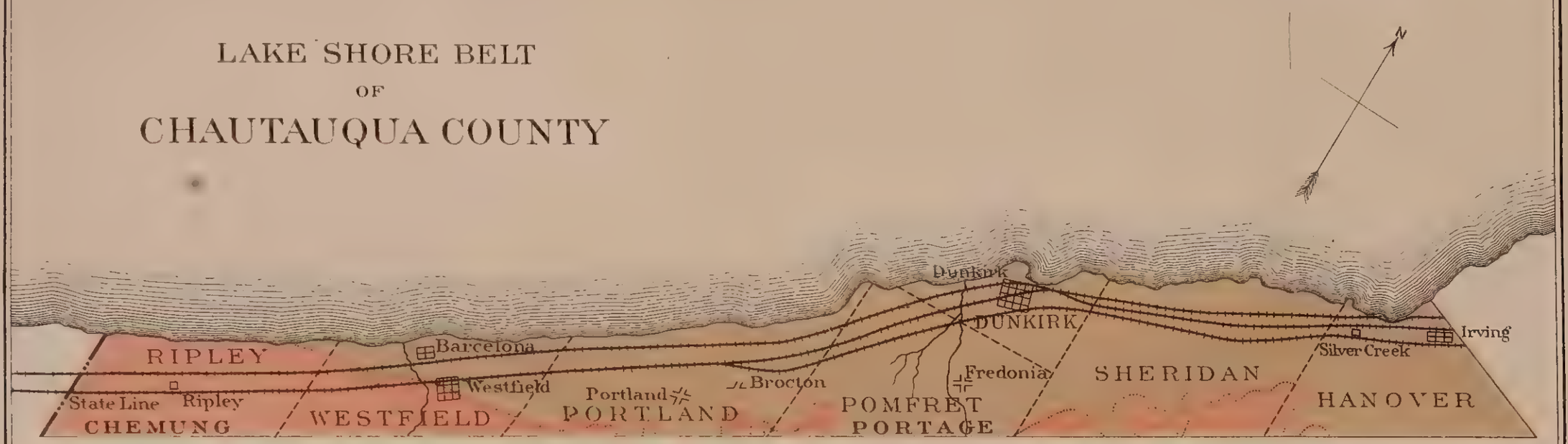
OF
CHAUTAUQUA COUNTY



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ence between the southern upland and the lake shore belt in both soils and climate is very marked, depending both on elevation and the presence or absence of the moderating influence of the lake.

The belt under consideration is wholly occupied by the shales of the Portage and Chemung groups of which countless outcrops appear in the valleys and gorges of the region.

The Portage beds occupy the immediate shore of the lake from Cattaraugus creek, which is the eastern boundary of the county, to the northeastern corner of Ripley township, where they descend to the level of the lake and are succeeded to the westward by the lighter colored but scarcely distinguishable shales of the Chemung group. Dark bands are frequent in the Chemung series also, but they are not as black as those found in the Portage. The most persistent element, according to Dr J. M. Clarke of the New York survey, is a sandstone bed, the place of which is near the top of the Portage. This bed is well shown in the quarries of Canadaway creek at Laona, three miles above Fredonia, and in the bed and banks of Chautauqua creek near Westfield and in many adjacent ravines. It can be distinctly traced for many miles as it affords the only building stone found in that part of the county and is accordingly opened, at least in a rough way, for neighborhood use, wherever its outcrops occur. The stone is, however, very hard, and has a great number of what the quarrymen call "dry seams," which give rise to frequent and irregular fractures.

The principal roadways through this belt follow in the main the old lake-ridges or beaches already referred to. The materials of these ridges are almost ideal materials for road making, and the roads of the region consequently have a high degree of excellence. There are few finer natural roads in the country than the main road from Buffalo to Cleveland and the Chautauqua section of it shows it to the best advantage.

The views across the fruitful plain here described from the summits of the uplands which constitute its southern boundary, 800 feet above the lake, are of unsurpassed loveliness. They are worth going many miles to see. The one to be obtained from the summit back of Westfield, to the west of Chautauqua creek, may be instanced as among the best.

To its fine and varied soils, with all that these imply, and its admirable and well tempered climate, the lake shore belt adds another advantage that has not yet come to due recognition. It holds in the uppermost 500 to 800 feet of shales that begin its geologic section, a stock of natural gas, not large in amount and low in pressure, but easily obtained, easily controlled and fairly persistent, from which the artificial light and heat of the region are already furnished to a small extent, and the supply of which can be increased and multiplied almost indefinitely. It is this last named element that is to be discussed in the present chapter.

Special interest attaches to the natural gas of the county because of the fact that utilization of it was begun here at an early date. The experience of Fredonia takes the foremost place in this connection. In fact, this little village, with its insignificant supply of natural gas, leads the way in the history of gas utilization in this country and is also widely known in the old world as well. This history will occupy the opening section of the present chapter.

a *Fredonia* (*Pomfret township*). Fredonia is a beautiful village situated immediately below the main beach or ridge which runs parallel to the present shore, separated from it by an interval of two to three miles and higher by about 200 feet. The size of this ancient beach and the amount of material composing it show that the lake stood for a long period, as time is counted in human history, at this level. Centuries at least would be required to account for its work. The present outlet by Niagara river had not yet been opened. Canadaway creek flows through the village. It is a considerable stream for Chautauqua county; in fact, one of the three largest of its list. It has a drainage basin of about 50 square miles, gathering its water in Arkwright and Pomfret townships from an altitude 600 to 900 feet above the lake. This gives a rapid descent to the stream. It occupies a new valley which it has worked out of the bedded rocks already named. From Laona northward, the valley is cut entirely in the Portage shales. The valley does not follow the joint lines of the formation but cuts across them at various angles.

The direction of the joint lines of the shales was measured for the survey by Ezra S. Ely, a civil engineer of Fredonia. There

are two sets of the joints, one being called north and south and the other east and west. The first set, instead of running in a due north and south direction, follows nearly a northwest course. (North 47° 45′, west, magnetic; true course, north, 52° west) The joint lines vary among themselves as much as three degrees. The cross joints are more frequent than the first set and cut the latter at an angle of 48° 30′, varying to 51° 15′ by needle. This brings their direction very nearly east and west. The north and south joints are not vertical but incline to the east, the extreme deflection measuring $2\frac{1}{2}$ in $10\frac{1}{2}$ inches. The cross joints incline to the southward. The intersection of these two systems result in the formation of oblong blocks, approaching regularity, which appear abundantly in the waste of the stream.

From some of these joints, gas constantly escapes. The currents are much weaker, however, at the present time, than they were in earlier days. When water occupies the openings formed by the joints, the gas appears in bubbles, forcing its way through the water. Such springs were known by the early French explorers of the country as *fontaines qui bouillent.*

Several of the most notable of these gas jets were situated in the bed of the creek within the limits of the village of Fredonia. The past tense is used in describing them for the reason that the escapes are too feeble to attract notice now, or have died out altogether.

These gas springs or jets could hardly escape the attention of the earliest human occupants of the region, white or red. Tradition says that the particular gas spring that gave such celebrity to the village in this connection was discovered by a traveler who went down into the creek bed for water and shade as he ate his midday lunch. This spring was located by the side of the Buffalo and Cleveland road, the oldest and by all odds the most important of the lake shore highways, where it crosses Canadaway creek. After the traveler had finished his meal and was striking a light for his pipe, he ignited the escaping gas. Whether the discovery was made in this way can never be determined; but there is an air of verisimilitude about the story that commends it to us. Certainly the discovery could well have been

made in some such way. Gas has no doubt been discovered scores or hundreds of times in this formation in similar ways.

At any rate, it became known in the early years of the century, when the permanent occupation of the lake shore belt was taking place, that inflammable gas was found in the bed of Canadaway creek, and indeed in many similar situations in this region. The surveyors of the Holland land co. were among these early discoverers. Moses D. Tennant, of Westfield, found in one of their old field books mention of a spring which emitted an "odorous air." The surveyors had traced it by the odor and had also found that this "odorous air" could be ignited. A score of years passed after this discovery before any new steps were taken in regard to it.

It was probably in 1821 when drilling was begun in Fredonia in the smallest experimental way for natural gas. Though the exact date is uncertain, the order of events is still held distinctly in the memory of some of the oldest residents of the village, who knew the persons concerned in the development and repeatedly heard the account of the several steps from their lips.

Two grist mills (flouring mills) had at the date named been established in Fredonia, one, north of the "Buffalo road" in the valley of the Canadaway and in almost immediate contact with the best known gas spring of this region; the other 15 to 20 rods south of the road above named and in the same valley. A woolen mill, in which home-made woolen cloth was manufactured was afterward built, immediately north of the second grist mill, by a man named Edward Howard. Mr Howard occupied for his residence a house directly across the road from the mill. The water well on his premises was unsatisfactory, being shallow in depth and its supply failing in dry seasons. The tail race of the grist mill passed directly under Howard's woolen mill, leaving the shale floor uncovered and plainly in sight below the mill floor. It occurred to Mr Howard to test the shale with reference to a better water supply for his dwelling, and he accordingly began work with an iron bar a few feet long, that was kept about the mill. After drilling into the shale beds a few feet, he observed bubbles of gas escaping through the water. He farther found that the gas was inflammable. Howard had a friend and companion in the person of William Aaron Hart, a gunsmith of

the village. Hart visited the mill from time to time and became interested in his neighbor's experiment and its outcome and determined to follow up farther the gas vein that had thus been disclosed. He continued working in the hole that Howard had begun under the mill till the extemporized drill gave way. In short, the drill broke, and the bottom of it was left fast in the shale bed, thus shutting off the principal flow of the gas already noticed. Not satisfied with this attempt, Mr Hart forthwith set about drilling for gas in the valley near by. The location was between the grist mill and the woolen mill. He went down 40 feet at this point, but found no considerable volume of gas. Still undiscouraged, he made one more effort to locate in the shale some one of the gas veins which had been escaping in the small way for centuries. He began this third trial in the valley north of the main road, and in fact just where the best-known natural flow of gas of the neighborhood had been observed.

How deep he sank the drill here can not now be ascertained. Some think that he went down 70 feet into the shale. At any rate, his search was successful. He found what was counted a good vein of gas and entered at once on its utilization. He constructed a rude gasometer in which to accumulate the gas and placed it under a still ruder shelter of undressed boards. He purchased light lead pipe, three quarters of an inch in diameter, and connected the gas with the old hotel (the Abell house) located where the Columbia hotel now stands. He also laid pipe to several of the stores on the opposite side of the street from the hotel. The natural gas supply of Fredonia was thus begun. The entire credit of its discovery and utilization belong to one man, William A. Hart. In his labors he showed both persistence and practical sagacity. We can well afford to honor his name.

This brief history made a profound impression on the country, specially when the condition of the times was taken into account. Fredonia was on the most common line of travel for this part of the country in that day, viz, the stage line between Buffalo and all the west which was then occupied. Travelers passing through Fredonia would be sure to have their attention called to the fact that here was a town lighted with natural gas; the first, certainly, in this part of the world. The phenomenon also attracted the attention of scientific men. The elder Silliman,

the distinguished professor of Yale college, published in 1831 an account of this experience in the scientific journal which originally bore his name and which afterward became the *American journal of science and art.* Fredonia became known even in foreign lands, on this same account. Sir David Brewster, the eminent scientist of Scotland, republished this same account in the scientific journal which he edited. As to the author of the account it is to be regretted that we have no knowledge. It was evidently furnished by some eye-witness of the phenomena. There are some inaccuracies in it, geologic and otherwise, but it clearly shows the interest excited by the facts. The article was copied, during the years to come, in many of the newspapers of the country. The account is as follows:

A village lighted by natural gas

The village of Fredonia, in the western part of the state of New York presented this singular phenomenon. The village is 40 miles from Buffalo and about two miles from Lake Erie. A small but rapid stream called the Canadaway, passes through, and after turning several mills discharges itself into the lake below. Near the mouth is a small harbor and lighthouse. When removing an old mill which stood partly over this stream in Fredonia three years ago, some bubbles were observed to break frequently from the water, and on trial were found to be inflammable. A company was formed and a hole, an inch and a half in diameter being bored through the rock, a soft fetid limestone, the gas left its natural channel and ascended through this. A gasometer was constructed and a small house for its protection and pipes being laid, the gas was conveyed through the whole village. 100 lights are fed from it, more or less, at an expense of $1.50 each. The streets and public places are lighted with it. The flame is large but not so strong and brilliant as that from gas in our cities; it is, however, in high favor with the inhabitants. The gasometer, I found on measurement, collected 88 cubic feet in 12 hours during the day. But the man who has charge of it told me that more might be secured with a larger apparatus. About a mile from the village and in the same stream it comes up in quantities four or five times as great. The contractor for the lighthouse purchased the right to it and laid pipes to the lake, but found it impossible to make it descend, the difference in elevation being very great. It preferred its own channel and bubbled up beyond the reach of the gasometer. The gas is carburetted hydrogen and is supposed to come from beds of bituminous coal. The only rock visible here, however,

and to a great extent along the shore of the lake is fetid limestone.—*Silliman's journal*, 17:398

Gen. LaFayette on his second and final visit to the United States in 1824–25, witnessed the unique spectacle of a village thus illuminated, and though not of a scientific turn, he could not fail to note the great interest of the facts. One of the oldest residents of Fredonia, Mr D. A. White, has given a circumstantial account of his visit, which was perhaps the most conspicuous event in the early history of the village and of which, as a lad, he was an eye-witness.

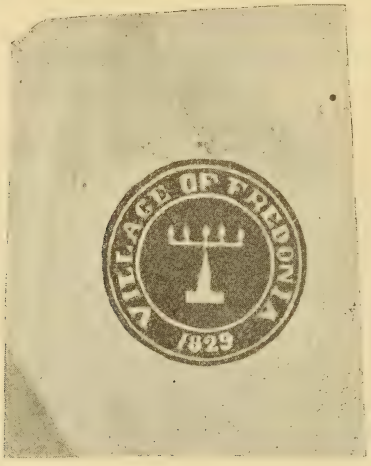
The general had wintered in the southern states and coming up the Mississippi and Ohio valleys had reached the boundary between New York and Pennsylvania near Jamestown, early in June 1825. He was brought from Mayville to Fredonia by Judge William Peacock, the first agent of the Holland land co. on June 3. Delays occurred in the journey and he did not reach Fredonia till two o'clock Saturday morning, June 4. He was en route for Dunkirk, where a United States sloop of war awaited him to convey him to Buffalo. A great throng had gathered to greet his arrival at Fredonia, including the military company of the village, which was to march as a guard of honor to Dunkirk. Refreshments were served, even at this untimely hour, by the light of natural gas, and Gen. LaFayette must be credited with this early experience in the use of a substance which we commonly think of as a discovery of our own times.

The well and its equipment changed hands after a little, passing into the possession of Jesse H. Starr, who followed the line of policy already established in the utilization of the gas. He seems, however, to have raised the price a light to a figure more nearly commensurate with its real value. The charge became $1.25 a quarter, or $4 a year, but the number of lights was insignificant. Some authorities say that 30 lights were supplied by the well, but others declare that the number did not exceed 12, at most. From the account in *Silliman's journal*, already quoted, it seems that the original price a light was $1.50 a year.

Jesse H. Starr died in the course of a few years, and his property, including the little gas plant, passed into the hands of his legal heirs. It became the duty of a brother, Joseph Starr, to

manage the gas plant for the benefit of the heirs and he continued the supply till about 1858, when a new stage in the history was opened. Before entering on this second stage, several facts of interest in the same general connection will be put on record.

The pride that Fredonia took in its unique source of artificial illumination is expressed in the village seal that was adopted in 1829. A photographic reproduction of an impression of the seal is herewith presented.



For the copy the survey is indebted to Mr D. A. White, whose kindly interest and service have been already noted. The size of the seal is reproduced in the engraving. It represents a gas pipe with five burning jets attached.

In 1829, or thereabouts, an attempt was made by Walter Smith, to furnish gas for the government lighthouse at Dunkirk. It is mentioned in the account in *Silliman's journal* previously quoted. In this attempt, Mr Smith was following an example already set in the lighthouse at Barcelona, 20 miles west, which will be described on a subsequent page. Mr Smith got possession of another gas spring in the creek bed, a mile nearer the lake than those already described. So sure of his ground was he, that he proceeded to lay a pipe line from the spring to the lighthouse. The pipe line consisted of pump logs properly joined together and two miles of such material laid in

the ground meant a not insignificant expenditure for the time at which it was made. The projector of the gas line had, however, overlooked two important points, viz, the difference in elevation between the spring and the lighthouse and the specific gravity of the gas. The latter is only about half the gravity of air. The spring is about 150 feet higher than the lake, and when the gas was turned into the line it had force enough to send it only half the distance required. Because of these facts the plan fell through.

The second stage of the history has already been referred to as beginning in 1858. Preston Barmore is the most conspicuous figure in the opening of the new chapter. In the year named, he began the development of a new and independent gas supply, one mile farther down the stream than the Main st. well. A notable escape of gas had been observed here from the earliest times. The boys of the village were familiar with it and had long carried on various qualitative and quantitative experiments of their own about it. The location was on the famous Risley farm where so many of the garden seeds of the early time were raised.

Mr Barmore secured a quarter acre of this tract in a strip a rod or two wide, adjoining the creek, and proceeded to dig a well near the gas spring. He had evidently studied the production begun by Hart 30 years before and had drawn from this two important inferences, viz, 1) that natural gas is to be found in the strata underlying the village, and 2) that the people were glad to pay for it, wherever and in whatever quantities it could be supplied, and he saw room here for a profitable investment of energy and capital.

The handling of the gas had heretofore been conducted in the village with the insignificant expenditures already reported. The original well had been drilled on the lands of the McPherson mill and the royalty on the gas was all embraced in the furnishing of two lights to the mill, the cash value of which, according to the original schedule of prices, was $3 a year. The drilling of the well had been accomplished in the same inexpensive way, the gunsmith, Hart, probably sharpening his own tools, and very likely doing the drilling himself at such times as he could obtain from his other engagements. Probably the only considerable

expenditure was that of purchasing the few hundred feet of lead pipe, three quarters of an inch or one inch in diameter, to convey the gas to the hotel and stores where it was burned. The gasometer is said to have had a capacity of 800 cubic feet, while the little shed that covered it was of rough lumber and its construction of the cheapest possible description.

In the autumn of 1858, Elias Forbes bought a half interest in the Barmore enterprise and a company was formed under the name of the Fredonia gas light co. This company is still in existence. The well on which the new business was to be established is said in one account to have been 30 feet in depth, with a diameter of six feet at the surface, increasing, cistern-like, to 20 feet at the bottom, where two vertical holes were drilled in the shale, one to a depth of 100 and the other to a depth of 150 feet.—Hamilton Child, *Chautauqua county directory*, 1874--75.

For the remainder of the year 1858 and for the next year about 2000 feet of gas were supplied to the village line every day. A gasometer of 12,000 cubic feet capacity was constructed and the introduction of gas into private residences for illumination was begun. In the course of a few years from that time, three miles of mains had been laid within the corporation limits, and for the first time the early designation of "a village lighted by natural gas" could be truly made as to Fredonia.

The company was soon obliged, however, to introduce manufactured coal gas into its pipes to maintain an adequate supply. They built retorts for themselves and found that by the introduction of a quantity of natural gas, the service of the coal gas was greatly improved.

A third stage in the history may be said to begin in 1871, when Mr Alvah Colburn drilled a deep well at his mill (the old Norton and Lester site, south of the Main st. bridge) for the purpose of obtaining fuel for the boiler of his mill. The Colburn well was drilled 1250 feet deep. A considerable supply of gas was obtained between 130 and 300 feet below the surface, but not enough for the boiler. Mr Colburn accordingly offered the gas to the company that supplied the village, and its service was greatly improved by the addition. This well is said to have produced about 4800 feet a day for a number of years and its rock pressure, the maximum of which it required 10 hours to accumu-

late, was 97 pounds. Mr Colburn sold the gas for $1 a thousand. This arrangement was continued for several years, till in 1875 he bought an interest in the company and finally bought out the entire plant. To keep up the gas supply he continued to drill new wells till he had put down 12 in all. These wells were 300 to 800 feet in depth. Six of them proved to be dry, but four of the original number are still producing gas. For 10 years he maintained the supply in this way, but with increasing difficulty. He then entered into a contract with the Gas co. of Dunkirk to undertake the supply.

The Dunkirk gas co. laid a four inch line to Fredonia, which is still in use, though no longer fully adequate to the demand. In order to close out its dealings with the Colburn estate, the Dunkirk company has recently sold the plant to Dr M. M. Fenner of Fredonia, president of the street railroad co.

In the Colburn deep well no. 1, the Corniferous limestone was reached at 1079 feet below the surface. Drilling was continued in the limestone 177 feet, thus making the total depth of the well 1256 feet.

Gas wells do not as a rule last more than four or five years at present, while formerly they retained vitality for at least twice that length of time. There are so many ways for water to find access now, that the wells are almost certain to be overrun within the limit named.

Leaving out of present account the various attempts to obtain gas from shallow wells for domestic supplies, which have been made within the last 15 years, it is necessary to put on record the resolute effort to find some large supply of gas that could be turned to account for manufacturing purposes.

This movement was no doubt inspired by the developments in Findlay and Lima, O., which began in 1884, and were under full swing in the course of the next year or two.

The reasoning in regard to the probable presence of high pressure gas at Fredonia was very convincing to those that had not studied the subject. It ran on this wise: "Gas has been seen to be escaping from the shales that underlie this region ever since it was first occupied. It was so at Findlay, O., but by boring a well there 1000 feet deep, an enormous volume of gas was brought to light, having a rock pressure of 400 pounds to the inch; why

should it not be so here?" By the autumn of 1886, this line of argument had served to convince a great many of the good people of Fredonia. It was reinforced by the appeals of a practical well driller, Mr J. W. Moore, of Warren, Pa. A public meeting was held in this interest in the latter part of August. Mr Moore offered to sink a well 2000 feet for $2000, and was willing to take $500 stock in the enterprise.

Most prominent among the friends of the project in Fredonia was Mr C. C. Camp. A company called the Fredonia gas and fuel co. was forthwith organized. $2000 was raised, and by September 1, the drilling contract was let. The officers of the company were C. C. Camp, president; O. D. Baldwin, secretary; F. R. Green, treasurer. A lot of one half acre in extent was bought of the Canning co., a half mile to the southeast of the village. By the last of October the tools were at work. By the middle of November the well was 1000 feet deep. At 1125 feet, the Corniferous limestone was reached, 46 feet lower, apparently, than in the Colburn well, but the difference of elevation in the well heads would cover much of the difference found.

At 1400 feet the tools were lost for a time. In December, the 2000 feet limit of the contract was approached, and at 1904 feet a strong vein of salt water was reached. The well had been drilled wet thus far. The first effort to exclude the water was by introducing 1700 feet of casing, which was presently found ineffectual. A few weeks later the casing was withdrawn and reset at something over 1900 feet.

The depth of 2000 feet was reached on Mar. 16, 1887. About this date the contractor visited the new fields of Ohio and reported great encouragement in regard to the Fredonia well from the facts that he found in the Findlay field. He urged that the well should be drilled 500 feet deeper. At 2100 feet, in the Medina sandstone a small gas vein was struck, but the drill soon passed into the red mud of the same formation. The contractor was reported as counting the situation favorable "for a strike in the next stratum below." When 2500 feet were reached, as nothing of value had been discovered reasons were found for drilling still deeper and still farther subscriptions were raised. The summer of 1887 witnessed but little progress in the work. Soon after starting on the last 500 feet stretch, the tools became fast

and were never got loose again. Nothing came from the expenditure of the $5000 raised among the people, except the insignificant volume of Medina gas above referred to and the valuable experience accumulated in the progress of the work. This experience served to uproot the delusion that because the slates of the surface everywhere carry low pressure natural gas, the deeper rocks must be charged with great volumes of high pressure gas.

The Medina gas vein, to which reference has been made, had a rock pressure of 150 to 160 pounds. Its daily production was about 7000 cubic feet. The vein has thus far proved persistent. The gas has but little illuminating quality. It was turned at first into the city gas mains, but its introduction brought instant protest from consumers. It has, however, excellent heating power. For the last five years it has been owned and controlled by Mr G. S. Phillips, who supplies his own residence and the houses of several of his neighbors with fuel. The well provides for four winter fires and for eight fires in summer. The property of the original company, including lands, well and fixtures has changed hands several times. In one instance it was sold for one tenth of the money originally invested. Even the small income resulting from the use described in the last paragraph will pay interest on the price thus reduced.

This prolonged experience of more than half a century had made it plain that the shales underlying Fredonia were everywhere charged with small quantities of low pressure gas. Gas escapes occur in the beds of all the streams, the only portions of the surface where the shales are entirely uncovered. In digging wells, also, inflammable gas is frequently found when the shale beds are approached.

This fact has naturally led to the drilling of numerous wells in and around the village, the sole object of which has been to obtain gas for artificial light and heat.

The most important cluster of these wells at the present time is on Central avenue about half way between Fredonia and Dunkirk. They are well represented by the three wells drilled by Festus Day, on his premises, for the supply of his own residence. Two of the wells were drilled 15 years ago, and have furnished

a full supply of light and heat for his own use ever since. The third well made no noticeable addition to the supply.

These wells are about 100 feet apart and 300 feet deep. They do not appear to affect one another in production. The gas is found at slightly different depths in each. The chief horizons where gas is expected are from 80 to 90 feet, 100 feet, 125 feet, and 165 feet. At 60 feet a small vein of strong saline and bitter water is found. All the water found in the shales is saline, but it can generally be exhausted by persistent baling when the vein is struck and when once reduced it makes but little farther trouble. When allowed to lie on the gas veins, however, it soon weakens or destroys them.

Mr Day is a practical oil producer and has thus recognized from the first the necessity of constant care of his wells. He never allows water to accumulate in them, but pumps them at least four times a year. To this care he attributes their continued vitality. The regulator is set at four pounds. He never shuts in a well completely, fearing that under the pressure new channels in the shale would be opened for the gas. In summer he sells the surplus gas. In past years he sold to the Dunkirk gas co. at 25 cents a thousand, but of late years, his neighbors are glad to pay $1 a thousand for all that he can supply. His income from this source sometimes reaches $30 a month. Taking everything into account he has probably received, during the last 15 years, as much money from his wells as he originally invested in them, while obtaining his own light and fuel free of cost. A moderate estimate of the amount saved in the last named items is $100 a year.

The neighbors of Mr Day, influenced by his example, have drilled many wells. Mrs D. L. Barker has one that has furnished the entire supply of light and fuel for her residence for the past 16 years. Dr Rolfe has a fair well, removed but a little distance from Mr Day's wells.

The cost of drilling and equipping a well 300 feet deep will not exceed $175 or $200. If such a well supplies a residence with light and fuel for two or three years, it has paid for itself amply, and if, thereafter, it keeps up the supply for 10 or 12 years, it has proved an excellent investment, better, in fact, than most men know how to make for themselves.

Nearer the village, still other wells have been drilled, but as a rule without equal success. Of the six wells that Dr Fenner has drilled on his home property, only one is reported to be as good as those already enumerated. When these wells fail it is generally through neglect in leaving the salt water on the gas veins.

The possibilities of a gas supply are to be found on many farms of the township, but it costs something to equip a house for the use of this fuel, and there is also an inevitable risk of failure in drilling a well. Considerations founded on such facts have held back farmers, as a rule, from making trial of their home supplies. The gas stock, however, remains safely stored in the rocks and as time goes by all of it will certainly be brought into requisition.

Comparatively little exploration in the way of drilling has been carried on in the townships of Dunkirk, Sherman and Hanover, but there is no reason to doubt that there are probabilities of natural gas supplies in all of them. In the western townships of the lake shore belt, considerable development has already gone forward. Three townships, Portland, Westfield and Ripley, will be taken up in the order named.

b *Portland.* The principal development in this township is on the eastern side and in the neighborhood of the village of Brocton. More than 40 wells have been drilled in the immediate vicinity of this village of which at least four fifths are successful as sources of light and heat. They also show good staying properties, a number of them having maintained their supplies for 10 or 12 years, without apparent reduction. The gas supply in the main is derived from depths in the shales between 25 and 250 feet. In a very few instances gas has been found lower than 250 feet, but no case is recorded in which it has been found 100 feet lower. Several wells have been drilled to 600 and 800 feet but no additions worth noting have been obtained in the lower portion of the sections. The gas is generally reported as derived from the black shale beds. The drillings or cuttings of this shale are reddish brown. This fact has sometimes led to naming the stratum in which the gas is found a "chocolate slate."

Water is always met in the wells. Near the surface of the shales the most reliable accumulations of fresh water for human

use occur. Great account is made of this fact in establishing domestic supplies. Good wells are generally possible at this horizon. As the drill descends into the shale, salt water is invariably struck. The strongest flow is generally met at about 70 feet below the surface. After being baled out at the time of drilling, a little will seep into the well, but less rather than more than one barrel a year.

Mr W. A. Crane, a driller of considerable experience in the oil fields of Pennsylvania, and who has done a large amount of work here for many years, recognizes some low anticlinals in the strata, trending to the southwest or south, but he is not able to detect any influence exerted by them on the gas production.

The rock pressure generally ranges from 60 pounds downward. A pressure of 25 pounds is counted eminently satisfactory throughout the township. Petroleum is sometimes found in small amounts. It occurs in a stray sand that is sometimes found in the shales. The oil is dark and heavy, serving for a natural lubricant when it is produced. The amount is in all cases small. A few barrels will exhaust the largest pocket.

The majority of the wells of the township are naturally in and directly around the village, but successful tests have been made north, east and west of this center. A rough list of wells drilled up to the present is here inserted.

Brocton bank	Haynes
Burton	Kinney
Butler, 3	Martin
Capwell	May, Harvey
Corell	Peck, 2
Crandall	Pettit
Crane	Powell, 2
Devenpeck	Ryckman, 3
Dunham	Smith, Frank
Edmunds, 2	Sullivan
Fay, E. H., 3	Unthank
Fuller, G. W., 2	Wenborne
Harris	Windsor
Hart	Wittmeier

S. B. Unthank found a peculiar condition in his well west of the center of the township. The gas appeared like vapor and

furnished an unusually brilliant light. The volume was also apparently satisfactory. It was estimated that the well would supply 10 or 12 stoves. It was drilled to a depth of 480 feet. For two weeks it rendered the best of service and then suddenly went out, like a light extinguished by a gust of wind. The facts reported make it seem as if one of the little petroleum pools already referred to had been tapped in this instance.

The Wenborne, Devenpeck and Sullivan wells were also failures, and one of the three Butler wells was also unproductive. All the others in the list have yielded more or less gas.

The amount yielded by some is very small, enough for a few lights only, while the daily production of others would show several thousand cubic feet. The C. N. Wittmeier well is probably so far the best well in the township. It is located a mile or so northeast of the railway station. It furnishes the entire fuel for two houses and in winter has kept three stoves in the wine cellar supplied, and has maintained, besides, 40 or 50 lights. All this service it has rendered without the rock pressure being depressed below 25 pounds. It was drilled four years ago and thus far has shown no appreciable shrinkage in quantity.

The next best well is that of Frank Smith, a mile east of the village. It does duty of the same general character as that above reported.

The Haynes well is exceptional in having required the longest string of casing known in the township, namely, 212 feet, salt water having been encountered near that depth. Its rock pressure is also the highest reported, namely, 60 pounds.

The Dunham well has an interesting history. It was drilled for Mr T. S. Moss on his own village lot. While visiting Ripley a few years since he saw a well that was being finished in the shale, the rock pressure of which was 25 pounds. He said to the driller that he would give him $1000 if he would find as good a well for him at his home in Brocton. The driller accepted the offer and put down a well on Mr Moss's village lot 600 feet deep, but the amount of gas seemed small. He shut it in, however, and put on a gage. In the course of two or three days the gage showed a pressure of 28 pounds. The driller accordingly demanded his money, but Mr Moss demurred. He feared that the gage had been tampered with. A second gage was borrowed

from the mill near by, but that showed the same pressure. Still hesitating to accept the testimony of the gages, Mr Moss obtained an instrument from the great locomotive works in Dunkirk, the reliability of which was guaranteed. When this confirmed the reading of the two already put on the well he saw that the driller had fulfilled his contract and made payment. This was 12 or more years ago. The well has been running ever since and without appreciable reduction in volume or pressure. It has kept the house constantly supplied with fuel and light and has never been uncapped. Though the driller received two prices for his work, the owner never made a more profitable investment.

G. E. Ryckman has drilled three wells on his premises. The first was carried to a depth of 400 feet, but there were no additions of gas below 200 feet. This well has kept the kitchen stove supplied with fuel for 12 years and has also furnished lights for the premises. The second and third wells have made but a small addition to the supply derived from the first.

c *Westfield.* This town has had almost as conspicuous a connection with natural gas as Fredonia. From a spring within its limits gas was conveyed in the early years of the century to the government lighthouse at the harbor on Lake Erie, furnishing in all probability the only light of this sort ever used in the world. Gas has also been developed by many wells in the village and applied to household service. Several deep wells have also been drilled here, but without results, except as they may have made some small contributions to our geologic knowledge. The lighthouse supply will be first described.

The harbor of Westfield was called in the early days, Portland harbor. The name was afterward changed to Barcelona. Chautauqua creek, which flows from the "hight of land," to the southward (the dividing ridge between the waters that flow into the Gulf of Mexico and those that are discharged into the Gulf of St Lawrence) is one of the largest streams of the county. It unwaters Westfield township and Chautauqua township in part, the balance of the drainage of the last named township going by Chautauqua lake to the Ohio river and thus to the Gulf of Mexico.

The descent of the creek from the upland, 1200 to 1400 feet above tide to the level of Lake Erie, 573 feet above tide, is mainly accomplished in three or four miles. The stream has cut its way through the soft Chemung shales, in a deep and picturesque gorge, the nearly vertical walls of which sometimes exceed 200 feet. Many short ridges of shale extend into the valley on either side, generally marking sharp bends in the main stream, but in some cases being referable to the entrance of adjacent tributaries.

The ridges are known as " hog's backs," " camel's backs," " pyramids," etc. In the lowermost two miles of its course the creek reaches the Portage shales and exposes in its bed and banks the upper members of this formation.

This deep channel held an important place in the exploration of the country by the French during the 18th century. Their parties were accustomed to cross from Canada to the Ohio valley and return by this very route. From the mouth of Chautauqua creek, which afforded a safe harbor for the small boats of which they made use, to the beautiful sheet known as Chautauqua lake, a portage not to exceed eight or ten miles was required. From Chautauqua lake the descent to the Ohio river at Fort Duquesne (Pittsburg) was easy, through the channels of the Connewango and Allegheny rivers. The old French road from the mouth of the creek was well known to the early settlers of the county. It was called the old Portage road. It crossed the Buffalo road (the main ridge road) one mile west of the village of Westfield. The point of crossing is now marked by an appropriate stone monument.

For the first half of the century Portland harbor received more or less attention from the general government. From 1820 to 1850 it was a fairly important harbor. Steamboats landed there daily or at least regularly during the summer months, and sailing vessels also found their way in numbers enough to cover all the business offered. But with the building of the Lake shore railroad the importance of Portland harbor ceased. The entrance became obstructed by the formation of sand bars derived from the materials transported by the creek in floods. The docks and piers passed into decay and after a little the harbor was entirely abandoned except by fishing boats.

A lighthouse was built for the government by Hon. T. B. Campbell of Westfield in or about the year 1828. Judge Campbell also owned the gas spring that had been recognized by the surveyors of the Holland land co. in the note already quoted from their field books. This spring, as indicated by the surveyors, was on lot 16, township 4, range 14. Influenced without doubt by the example of Fredonia in its recent utilization of natural gas, it appears that Judge Campbell made an agreement to pipe the gas from his spring into the lighthouse and to supply the lights for the same price that the government would pay for the oil required to maintain them. We learn this from two records in a publication of the general government entitled *Documents relating to lighthouses,* 1789-1871. The first of these records is a report from Lieut. C. T. Platt, dated Geneva, N. Y. Nov. 26, 1837, (page 57). It reads as follows:

Portland lighthouse. Lighted with natural gas, 11 lamps and reflectors. Stationary. Owing to a failure of gas that may be attributed to the extreme drouth, oil is now substituted. It is presumed, however, that the fall rains will replenish the streams from which the fountain is supplied and thus prevent the escape and leakage of the gas. The recurrence of such a drouth, will, if ever recurring, be at great intervals, and will not probably render the use of oil for a long time necessary.

On another page of the same volume, namely, page 769, we find a communication signed by Lieut. S. Pleasanton and addressed to Hon. Thomas Corwin, secretary of the treasury. The communication bears date June 7, 1851. In it the following passage appears:

We have one lighthouse on Lake Erie, lighted with natural gas, conveyed a distance of two miles in pipes and even here we are obliged to keep oil and lamps, as water frequently collects in the pipes, over which the gas will not pass, and whilst they are taken up and freed from water, oil light has to be used. We have a contract for supplying the natural gas at the annual cost of the oil that would be required if lighted with this material.

The language of these extracts is in both cases somewhat ambiguous, but what the writers evidently meant to say can be clearly made out. The effect of a severe drouth on the gas supply seems to have resulted in a waste of the gas. The main and

natural channel was deserted and numerous insignificant escapes took its place. The return of the water of the stream would shut off the latter, restoring the original flow.

Judge Campbell's gas spring, the one in question, is about three quarters of a mile from the lighthouse (not two miles, as the last document makes it). It occurs in the floor of a little stream called Tupper's creek, and but a few rods back from the lake. The joint lines in the Portage shales are very distinct at this point, appearing as if a slight uplift had been experienced by the shales. In direction they agree with those already described in the bed of Canadaway creek at Fredonia. The two main systems are approximately *northeast-southwest*, and *east-west*. Other directions are also found in subordinate joint lines. The "odorous air," noticed by the old surveyors, is still in evidence. One entering the ravine, either from the lake or the highway, will easily find his way to the escaping gas by its unmistakable odor. The spring was marked at a still earlier day by the French explorers of this region as a *fontaine qui bouille*. At a later date this immediate neighborhood was investigated as a source of salt. A so-called salt well was dug near this point in 1815. It was very shallow and nothing came from this search. The not unwarrantable expectation seems to have gained entrance to the minds of some that where one form of mineral wealth occurs other forms are likely to be found. Drilling at any point in the neighborhood for a few scores of feet would undoubtedly have revealed the presence of salt water.

No effective means for accumulating the gas have ever been employed. Iron pipes are thrust into the crevices of the rock to catch what they can. At the present time the supply is very scant, not enough for even a single fire. In the days when the lighthouse was supplied, wooden pipes (pump logs) were employed to convey the gas. When the harbor and lighthouse were abandoned, an effort was made to secure the gas spring for the service of the village of Westfield. In working toward this result the property changed hands several times. It is not necessary to follow these changes in detail. In 1864 Judge Campbell first sold the property. Among the subsequent owners were David H. Taylor, the Barcelona petroleum co., the First national

bank of Westfield, and the Westfield gas co. (by Dr S. B. Brewer, president). It is now owned by the Phoenix gas and improvement co. of Philadelphia, having been recently purchased from the executors of Dr Brewer's estate. In October 1866, the village corporation gave the right to the gas company to lay mains through the streets for the purpose of supplying public lamps. A two inch iron pipe was laid from the village to the spring about that time and the use of the gas was at once begun. The supply, however, was found inadequate and it soon became necessary for the company to enter on the manufacture of coal gas. This has been continued to the present day, the supply being helped out by the small quantity of natural gas furnished by the well.

About 1865 the Barcelona petroleum co. drilled a well in the neighborhood already described to the depth of a few hundred feet. No oil was found in it, but it yielded a moderate supply of gas. The well was drilled wet and was soon overrun with water, but the gas supply has not entirely ceased even yet. Two or three years since, a measurement of its quantity was made and it was found to be still giving off about 1800 cubic feet a day.

Dr Brewer also drilled a well near the gas works for the purpose of turning the supply into the village line. He struck two gas veins, one at a depth of 500 feet, and the other at 1100 feet, but the production of both was so small that no account was taken of it.

In recent years wells have been drilled in the village to obtain household supplies of light and heat and a number of them have been successful. One of the best instances is found in the experience of Mr Reuben G. Wright, who resides one half mile east of the village center. Mr Wright had seen the result of much of the drilling previously recorded and had concluded that the weak supplies of gas belonging in the shales were permanently discouraged by the heavy body of water that was allowed to lie on them in the process of drilling. In a well that he began 14 years ago, on his own village lot, he cased the water off at 120 feet. He found a small volume of gas at 200 feet and an additional supply at 500 feet. The well was drilled to a depth of 900 feet. The amount of gas was small and the rock pressure feeble, the latter not exceeding three or four pounds. But, after

all, the well yielded gas enough to light his house and to supply the kitchen range with fuel. Encouraged by this experience he drilled two more wells, five or six years since, to add to his supply. These wells he did not carry to a greater depth than 550 and 600 feet. They were very like well no. 1 in all respects and he is now able to supply his house with light and heat, except that for a few months in winter it is necessary to supplement the gas by a coal fire in the furnace.

Several other partial successes have also been gained in this same line. Mr J. G. Apple, an experienced oil operator, has put down a deep well on his property in the village.

In 1894 a test well was drilled on the old paper mill property, a mile or two south of the village. A company was organized by the efforts of a "prospector" named Adams, from Erie, Pa. Among the citizens who took the greatest interest in the test was Mr Herman L. Kent, who has kindly furnished information in regard to the drilling.

It is said that the principal argument of the prospector for the location was drawn from a line connecting Bradford, Pa., with the Canadian gas fields, but this line is a northwest line and Westfield is not on it at all. It is, however, almost a relief to find an "oil expert" adopting a line other than a northeast one. It is probable that gas was looked for in the Medina sandstone, and the facts from Canada were used to support this view. A uniform dip was probably looked for in the strata and the calculation made from that as to the depth at which the Medina would be found.

The drilling was started by 10 persons, each of whom subscribed $200. They contracted with Mr Adams to drill to a depth of 2500 feet at $1 a foot. A company was afterward formed by six of the persons already interested, under the name of the Westfield fuel and light co. Leases were then taken on property that it seemed wise to control. Gas veins were struck in this well at about 1000 feet and also at 1300 feet. At 1500 feet a heavy flow of salt water was encountered, which completely filled the well. The new company proceeded to drill still deeper. An addition of $2000 was raised for this purpose among its members. After several unsuccessful attempts, the well was cased at a depth of 1608 feet. After a little progress below this

point the tools were lost. Some say that they were lost at a depth of 1800 feet, others at a depth of 2000 feet. A one inch pipe brought up the gas that was previously found, and it was kept burning for a long while. Interest in the scheme gradually died out and the owner of the land has lately resumed his right to the property and has removed the derrick.

The Devonian limestone was undoubtedly reached in the drilling, but no record seems to have been kept as to its exact depth. This was really one of the most important facts this well should have been able to supply. It is said that the contractor counted himself within 100 or 200 feet of the Medina sandstone when the drilling tools were lost.

The people of Westfield spent $4000 on this test and nothing resulted from it. The driller recognized two sand rocks in the series penetrated; one at 1000 feet, 30 feet thick, and another at 1300 feet and 20 feet thick. Both proved to be reservoirs of gas. The volume was small but the supply seemed fairly persistent.

The rock pressure of the shale gas is weaker in Westfield than in Portland, to the east, or in Ripley, to the west. The natural escapes of the gas, like the well known one at the lighthouse spring and at other points under the waters of the lake, from which gas is constantly rising, are counted by some an adequate explanation of this low pressure, but it should be remembered that similar vents are found in the other townships named.

d *Ripley.* All the surface rocks of the belt under consideration in Ripley are of Chemung age, the Portage group going under cover on the eastern line of the township. The series consists as largely of shales as those of the townships previously described, albeit they differ somewhat in character and composition from the latter.

Within the last 12 or 15 years this township has developed its gas resources more fully than any other in the county, unless Portland be excepted, and probably no exception is needed even in this case. Wells have been drilled westward to the Pennsylvania border and while they are multiplied at the village center they cover territory several miles to the eastward, and excellent success has been also registered in trials three to four miles south of the lake and thus well up on the rising ground of the hillside.

The following list embraces most of the best known wells. The number is sure to be rapidly multiplied.

Dexter Alfred
H. A. Burton
B. J. Horton
Bert Johnson
Orson Keith
Mrs Walter Loomis
George Martin
Alfred Palmer
E. C. Porter
Frederick Randall, 7
Nelson Randall
W. P. Rickenbrod
Frank Spencer
Edward Taylor
D. G. Tennant
Theron J. Walker, 5
John Wethy

The general depth of the wells is at least 600 feet. The rock pressures range from 85 pounds downward, but in all the wells that are counted satisfactory it is at least 20 pounds. The figures generally range between 20 and 60 pounds. The gas veins are light, as a rule, but " blowers " are sometimes met with. The first gas is expected at 125 to 130 feet. The best supplies seem to come from the blue shales of the Chemung. A belt of hard black slate is found in the wells 100 to 150 feet in thickness, and about 500 feet below the surface. It belongs to the Portage division. This is a sort of " farewell " rock for the driller of shallow wells. He has learned to depend on the gas veins that are found above this bed. He also finds that wells are safest when separated by a considerable interval. The best experience seems to be in favor of a quarter of a mile, but this interval is impracticable in many instances.

Of the 27 wells named above there is but one failure so far, and this scarcely deserves to be so counted. Its history is as follows: Orson Keith drilled a well for water. He did not find a good vein, but at the depth of 150 feet a considerable volume of gas appeared and he concluded therefore to save the well for this use. For a time its service was entirely satisfactory. But one day it suddenly dropped off like a light blown out. It so happened that at this identical hour 200 feet of water were being removed from one of the Randall wells, three miles distant. The removal of the water may have allowed the gas to rise to a higher level and thus have destroyed Mr Keith's supply. If the Randall well should again be filled with water and the Keith gas should

then return, the demonstration of the connection between the two would be complete.

In the exploration in Ripley Mr Nelson Randall was the pioneer, beginning the work in 1882. He was led to believe that the shales of the township hold a supply of gas by reflecting on an observation he had made many years before while rowing on the lake, a half a mile or so from the shore. He noticed there a bulging surface of the water and on closer examination found that it was due to escaping gas. The gas he found to be inflammable and he properly concluded that it was derived from the underlying rocks. He began at this time to urge his neighbors to unite with him in a test, but failing to interest others he finally undertook the drilling himself in the year above named, 1882. He drilled a well on his own premises, 780 feet in depth. At 230 feet he found a salt water vein and sunk his casing below it. His well yielded a respectable volume of gas and has supplied without interruption since that date two dwellings with all the fuel and light they require. In addition it has maintained a considerable number of lights in other residences.

His neighbors have now followed his example and wells have been considerably multiplied, as the list above given shows. This increase of wells around the village center will undoubtedly affect the production of all before a very long time.

Mr Frederick Randall, son of Nelson Randall, has laid a two inch pipe through the village streets and has attached to it seven wells, the farthest of which is about two miles to the westward. From this line he supplies a number of households with fuel and light. As the number of wells attached to the line is increased the gas supply becomes more satisfactory. The irregularities of supply that result in the use of a single well disappear when several wells are connected. In the village of Northeast, Pa., in the next township west, not less than 14 wells are connected with a single line and great advantage results from this equalization of flow.

Dr D. G. Tennant, living at the village center, obtained gas for his house for a number of years from the well of his next neighbor, who had a surplus. But several years ago he concluded to drill a well for himself. Since that time no other fuel or light

has been brought into his house and he is also able to supply one of his neighbors with light. No signs of exhaustion appear in the supply thus far. The original rock pressure was 24 to 30 pounds. Under winter use it declines somewhat, but the summers have so far seemed to restore it. The well is 670 feet deep and is cased with five and five eighths inch casing to a depth of 150 feet.

Mr H. A. Burton drilled a well in 1896. The drill passed through 550 feet of blue shale, and then struck the black band, which proved to be about 100 feet in thickness. At 701 feet a "blower" of gas was struck, which was very noisy for a few days. Its roar could be heard several miles away. Its pressure at the time exceeded 100 pounds to the inch, but it soon fell to 40 and finally to 25 pounds. Fearing lest the two veins of unequal pressure might interfere with each other, the owner separated them, bringing them up by different pipes, both of which are under control. He has used thus far, only the gas of the upper vein. The supply from this source has proved adequate for three households in the winter and for five in summer. The lower vein has a pressure of 20 to 24 pounds. There seems no reason to believe that the well would be endangered by its utilization at the present time in connection with the upper vein.

In the fall of 1897 Mr George Martin drilled a well for gas on his premises which proved successful. It furnished a good supply of fuel for his house. An examination of the well a few months after it was finished revealed the presence of oil in it in considerable quantity. As usual, the oil is of lubricating character and apparently of very good quality. The quantity in such cases frequently amounts to 15 or 20 barrels.

The gas supply from the shales continues along the lake shore border for 175 miles beyond the western boundary of New York. The shale formation extends with unbroken continuity from Chautauqua county westward through Erie county, Pa., and through Ashtabula, Lake, Cuyahoga and Lorain counties, O., terminating at Huron, O. Throughout its entire extent it gives rise to the kinds and conditions of gas production that have been described in the preceding pages. Hundreds of wells have been drilled throughout the portions of the belt here named and the number is being constantly multiplied. There has been

a large development in Northeast, Pa. during the last 20 years. Wells have been drilled here by the score and in still larger numbers at Erie, a few miles farther west. Within the city limits of Erie the gas of the underlying rocks has been reduced to incipient exhaustion by the number and close proximity of the wells put down.

In Ohio, tests have been made in every county of the lake shore belt. In the thriving villages along the line many wells have been drilled and the gas has been utilized in each to the value of thousands of dollars, annually, as counted by the fuel it displaces.

Origin of the gas.

That the gas of the shale belt is derived from petroleum stored in the same rock series seems highly probable. There is no difficulty as to the storage of the petroleum. The clays which constitute a large percentage of the shales have a natural affinity for mineral oils, absorbing and retaining them indefinitely. That petroleum is present in the series is proved not so much by the pockets of it containing a few gallons or a few barrels, as the case may be, that are occasionally reached in the process of drilling, as by its universal diffusion through the substance of the shales. In many instances every fragment of the shale, blue or black, brought up from a well, discloses the presence of petroleum to the senses of both smell and taste. The percentage is small, but the total amount of petroleum is considerable. A few years since an examination was made of drillings taken from 1000 feet below the surface at North Kingsville, Ashtabula co. O. The petroleum was extracted by treating the shale fragments with bisulphid of carbon, after they had been reduced to as fine a state of division as possible in an agate mortar. The result was the demonstration of the presence of at least one tenth of 1% of petroleum, *as such*, in the shales. Now if the series of 1000 feet is fairly represented by this determination, what amount of petroleum does it contain? The figures stand for a layer of petroleum one foot thick. This would amount to more than 328,000 gallons to the acre.

That petroleum gives rise to gas is a matter of common observation, and therefore the only question with which we are con-

cerned relates to the origin of the petroleum. If we can determine its history we can learn also the history of the gas that is now found there. That the latter could arise by destructive distillation of the organic matter of the shales is certain. Even the number of gallons of oil to the ton that those portions of the series richest in organic matter can furnish has been determined. It is entirely conceivable that these stocks of bituminous matter may all be needed in the ages to come and that the distillation of the shales may be carried on in the future on a large scale for the purpose of securing these sources of light and heat, but there is no sound reason for believing that any process of distillation is now going on in the strata. The petroleum and gas are found alike in all the varieties of shale, in the blue beds as well as in the black. The preservation of the petroleum, if it took its origin when the organic matter buried in the shale was fresh, presents no difficulty. Petroleum, when sealed in the strata, is a permanent substance, as durable, for aught we know, as coal. No reason can be given why it should not last, as coal does, through a dozen geologic periods. In the region that has now been described the shale is covered with a comparatively thin deposit of drift and in the beds of the larger streams and also in many of the smaller streams it is not covered at all, or, with only a shallow depth of water.

It is in these last named localities that all the natural gas springs of the district are found, but there is no reason to believe that there is any more gas in the particular areas which the accident of drainage has laid bare, than in the territory at large. At the points named, there has been an open way for the escape of gas, but undoubtedly had the valleys been established elsewhere the phenomena would have been repeated.

Another fact that points to the universal diffusion of gas throughout the shales, is the discovery of successful wells in and around every considerable village of the belt. At these village centers there is wealth enough to multiply tests and at all of them gas is found in greater or less quantity. If the villages had been located elsewhere the results would have been the same.

It may be asked why the presence of gas is restricted to a single district as the lake shore belt. As the shales pass under cover to the southward they retain, without doubt, their gaseous

contents, but as soon as we go back from the belt under consideration the depth of the wells must be increased and the additional trouble and expense of taking care of the water veins that are found in the descent is greatly increased. The small gas veins that are due in the lower horizons can no longer make anything like an adequate return for the necessary expenditure, even when the wells would be counted ordinarily successful if drilled in shale territory.

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